CIENCIA 16(2), 156 - 166, 2008
Maracaibo, Venezuela

Linking environment and angling success at Humacao Natural Reserve lagoon system, Puerto Rico

Orlando J. Ferrer Montaño and Eric D. Dibble*

Department of Wildlife and Fisheries. Mississippi State University, P.O. Box 9690, Mississippi State, MS 39762, USA.

Recibido: 20-01-07 Aceptado: 15-07-08

Abstract

The Humacao Natural Reserve (HNR) lagoon system (Puerto Rico) provides surrounding communities with important fish resources where diverse fishery interests overlap. Fishes targeted include tarpon (*Megalops atlanticus*), snook (common snook *Centropomus undecimalis* and swordspine snook *C. ensiferus*), and tilapia (Mozambique tilapia *Oreochromis mossambicus* and redbreast tilapia *Tilapia rendalli*). We tested the utility of several meteorological, environmental, and biological variables as predictors of fishing success, represented by mean daily harvest per unit effort (HPUE) of creeled fishes with the intention of providing anglers of the HNR lagoon system with general assistance to improve harvesting. Values of HPUE and the remaining variables were generated as part of a broad project effort to evaluate the fisheries at HNR. Results of multiple regression analysis and canonical correspondence analysis indicated that it was possible to generate models amenable to biological, meteorological, and environmental interpretation. Most of the variables used in these analyses are easily gathered or observed by anglers; it appears that anglers willing to fish successfully at HNR would benefit from this type of information.

Key words: multiple regression analysis, canonical correspondence analysis, angling success, coastal lagoon, Puerto Rico, Caribbean Sea.

Conexión entre el ambiente y el éxito pesquero en el sistema lagunar de la Reserva Natural de Humacao, Puerto Rico

Resumen

El sistema de lagunas de la Reserva Natural de Humacao (RNH), Puerto Rico, provee importantes recursos pesqueros a las comunidades circundantes, donde se solapan diversos intereses. Los peces capturados incluyen el sábalo (*Megalops atlanticus*), el róbalo común (*Centropomus undecimalis*), el róbalo espina de espada (*C. ensiferus*), la tilapia mozámbica (*Oreochromis mossambicus*) y la tilapia pecho rojo (*Tilapia rendalli*). Comprobamos la utilidad de algunas variables meteorológicas, ambientales y biológicas como pronosticadoras de éxito pesquero, representado por el promedio diario de la cosecha de peces por unidad de esfuerzo (CPUE), estimado a través de censos a pescadores mediante la denominada metodología del censo tipo creel, con la finalidad de proveer asistencia general a los pescadores del sistema lagunar de la reserva para mejorar sus capturas. Los valores de CPUE y las demás variables fueron generados

* Autor para la correspondencia. Telefax: 58-261-7985629. E-mail: carichuano@hotmail.com.

como parte de un proyecto para evaluar las pesquerías de la RNH. Los resultados obtenidos a través de análisis de regresión múltiple y análisis de correspondencia canónica indicaron que es posible generar modelos interpretables desde puntos de vista biológicos, meteorológicos y ambientales. La mayoría de las variables usadas en estos análisis son fácilmente obtenidas u observadas por los pescadores. Los resultados indican que los pescadores de la RNH que deseen ser exitosos pudieran beneficiarse de este tipo de información.

Palabras claves: análisis de regresión múltiple, análisis de correspondencia canónica, éxito pesquero, laguna costera, Puerto Rico, mar Caribe.

Introduction

Four aspects must be addressed when evaluating angling: the resource, the activity, economic considerations, and participant behavior (1). With respect to the last aspect, it is evident that fishing objectives play particular roles in the evaluation. Studies indicate that sometimes angling can be viewed just as a leisure experience that is chosen from many alternatives (2); it is the case, for instance, when people fish for sport or pleasure. However, when people fish to fulfill food needs, the situation is totally different. In this last regard, managers and researchers are committed to develop methodologies and guidance to not only exploit and conserve fishery resources more efficiently, but also to help anglers to be more successful in catching and harvesting fishes in which they rely to supplement their diets.

The fisheries at Humacao Natural Reserve (HNR; Puerto Rico) are good examples of fishing activities where diverse fishery interests overlap (3-4). The reserve has a brackish water lagoon system where important fisheries have developed. Recreational anglers, sport anglers, and subsistence anglers exploit the fish resources of HNR (3-4); all of them with different motivations and interests. Nevertheless, like any other fisher, they all wanted to be successful catching their favorite fish, and asked for recommendations to improve harvesting at HNR. Thus, this called for efforts to forecast harvest success in the HNR lagoon system.

Management authority in the reserve falls entirely under the hierarchy of the Puerto Rico Department of Natural and Environmental Resources (DNER). To date few studies have examined the fishery status of the reserve in terms of its ability to provide angling satisfaction. Only hook and line fishing is allowed on HNR, and though there currently are no harvest regulations for the HNR fisheries, the reserve's management authority encourages fishers to only harvest the largest fish (especially tarpon and snook). Tilapia (Mozambique tilapia *Oreochromis mossambicus* and redbreast tilapia *Tilapia rendalli*), introduced fish species to Puerto Rico and which have an extremely high reproductive success in the lagoon system, is the main supporter of the fisheries. Most anglers fish the lagoons seeking for tilapia (4).

Using a research approach that explicitly addressed fish populations, habitat availability and characteristics, and human relations with the resources, Jackson et ál. (5), Ferrer Montaño (3), and Ferrer Montaño et ál. (4) investigated ways to integrate environmental and ecological information with social aspects at HNR. In this paper we tested the utility of several meteorological, environmental, and biological variables as predictors of fishing success using multiple regression analysis and canonical correspondence analysis (CCA). The overall goal of this study was to relate fish harvest rate to a tractable suite of readily measured or computed variables, and to provide anglers, particularly sport and recreational anglers, of the HNR lagoon system with general assistance to improve harvesting of their targeted fishes. In this regard, harvesting improvement does not necessarily mean catching more fish, but quality fish instead.

Materials and methods

Study area

Humacao Natural Reserve is a relatively small protected area located in eastern Puerto Rico (18° 10'N, 65° 46'W) (Figure 1). It has a brackish water lagoon system that was created by Hurricane David and Tropical Storm Frederick in 1979. Six lagoons compose the system: Mandri 1.67 ha; Mandri 2.74 ha; Mandri 3.52 ha; Santa Teresa 1.27 ha; Santa Teresa 2.24 ha; and Palmas, 5 ha. The lagoons are arranged in a series that connects to the Caribbean Sea through the Antón Ruiz River. Since its creation, the HNR lagoon system support fisheries that contribute consumptively as well as aesthetically and non-consumptively to the surrounding communities (3, 5). Fishes targeted are tarpon (*Megalops atlanticus*), snook (common snook *Centropomus undecimalis* and swordspine snook *C. ensiferus*), and tilapia (Mozambique tilapia *Oreochromis mossambicus* and redbreast tilapia *Tilapia rendalli*).

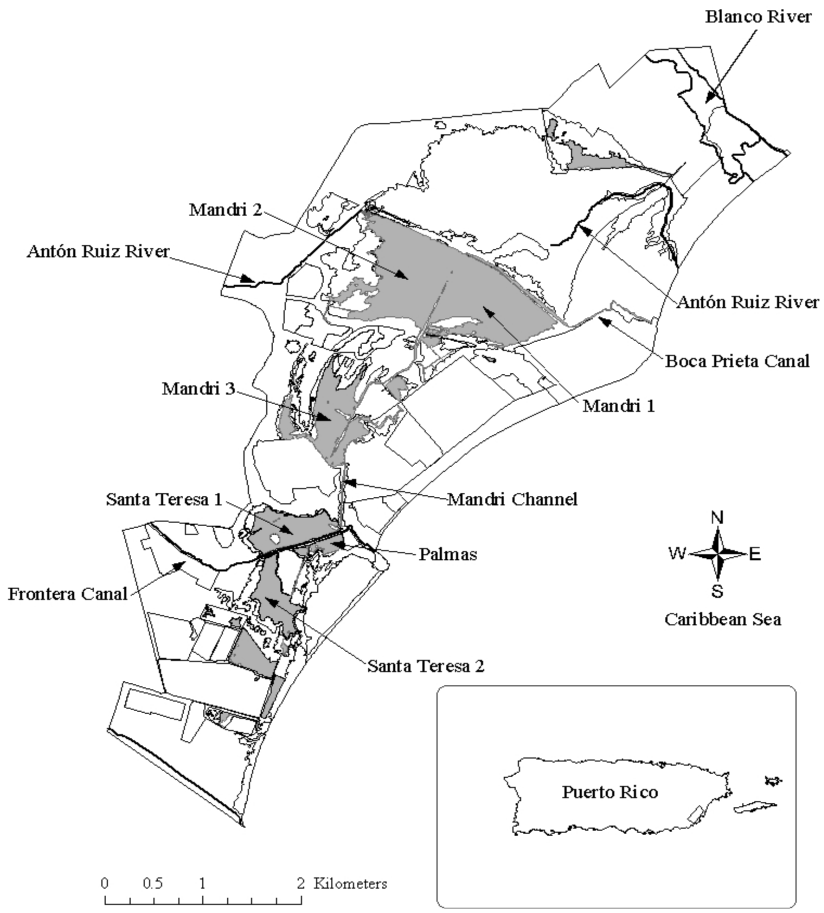

Figure 1. Map of Humacao Natural Reserve, Puerto Rico showing major hydrographic features. Figure courtesy of Marisel López and José Burgos, Department of Wildlife and Fisheries, Mississippi State University.

Data and sources

Data used in this paper were collected as part of a broad holistic project effort (3-5) intended to integrate environmental and ecological data with social aspects at HNR. This project included a creel survey conducted from April 2000 through March 2001 to generate monthly estimates of fishing effort and harvest for each creeled fish species (i.e., snook, tarpon, and tilapia) from the lagoon system. The survey interviewed 343 anglers, with a total estimated annual effort of 26,581 angler-hour and a total harvest of 107 tilapia, 58 snook, and 16 tarpon accounting 107.4 kg. The survey identified three groups of anglers: (1) recreational anglers (N = 219), for whom fishing was simply an outdoor activity; (2) sport anglers (N = 42), who had greater expectations regarding fishing as an activity, requiring privacy; (3) subsistence anglers (N = 82), for whom the HNR lagoon system represented a permanent and affordable source of fish protein.

The holistic project also included collection of fishes and invertebrates with several sampling gears (i.e., gill nets, trap nets, light traps, seining, and pop nets) and strategies, and examination of the physicochemical and habitat structure of the lagoon system between March 2000 and May 2001. In addition, several meteorological variables were also collected. All these variables were tested in different statistical approaches to relate them to fish harvest collected from the creel survey. Fishing success was evaluated by estimating mean daily harvest per unit effort (HPUE) of creeled fish; although many anglers recorded all fish caught, only fish actually retained by them were used to estimating HPUE.

For population assessment sampling purposes, all lagoons were considered as distinct units and sampled on an individual basis. Each lagoon was divided into six sections that served as experimental units. These experimental units covered the entire sampling area and did not overlap, and were small enough to all fishes present at a given sampling date could be assessed. Each section was marked with global positioning system coordinates and assigned a number from one to six. During each sampling period, gill nets and trap nets were deployed within one of these areas selected at random.

For assessment of invertebrates and early life stages of fishes, each lagoon was divided into four sections that served as experimental units. Each of these sections covered most representative microhabitats identified in the HNR lagoon system. Each section was marked with global positioning system coordinates and assigned a number from one to four. During each sampling period, one of the four sections in the respective lagoon was chosen at random, and light traps and pop nets were set in representative microhabitats. Supplemental sampling by seining was conducted at all available seining beaches. All these sampling gears and strategies allowed us to collect a broad range of fish species and life history stages in the lagoon system. Relative abundance (catch per unit effort, CPUE) of fishes (fish/gear-set) and invertebrates (individual/gear-set) were determined independently for each sampling.

Environmental variables were measured at each sampling site to characterize habitats and their relationships to the fish and invertebrate assemblage dynamics. Variables measured were depth (m), Secchi transparency (m), water temperature (°C), dissolved oxygen (mg/L), specific conductance (μS/cm), salinity (ppt), total dissolved solids (g/L), turbidity, Nephelometric Turbidity Units, NTU, pH, and dissolved oxygen percent saturation (%).

Regression analysis

The utility of the above mentioned variables as predictors of fishing success, represented by mean daily harvest per unit effort (HPUE) of creeled fishes, was evaluated with multiple linear regression (SAS, PROC REG; 6). The interactive stepwise method, which includes forward selection and backward elimination, was selected as the sequential variable selection procedure. Regression residuals were analyzed to identify deviations from linearity and model suitability. When pertinent, variables were transformed to meet criteria of normality and homogeneity of variance; commonly performed transformation was logarithmic. Collinearity was diagnosticated with the variance inflation factors. These factors measure the inflation in the variances of the parameter estimates due to collinearities that exist among the regressor (independent) variables (6). The intention of these analyses was to select the best models based on the highest overall R^2 values, the lowest residual variance, absence of collinearity, and underlying assumptions according to residual plots. If two or more predictors were selected for a model, standardized regression coefficients were calculated to compare the relative importance of the predictor variables in describing response variables (7). The significance level for entry into the model was set at $\alpha = 0.2$, and the significance level to stay was set at $\alpha = 0.1$. Levels of statistical significance for all analyses were set at $P \leq 0.05$.

Values of HPUE for each targeted fish generated by the creel survey for each creel day were utilized as response variables, whereas for predictor variables we created a data matrix composed of the three types of variables collected. Meteorological variables selected were precipitation the day of creel (cm), precipitation the previous day (cm), mean air temperature (°C), mean barometric pressure (mmHg), and mean wind velocity (kn). Daily precipitation was obtained from a rain gauge at HNR, and the remaining variables were obtained from the National Climatic Data Center, Asheville, North Carolina. These data were from the Roosevelt Roads U. S. Navy weather station, approximately 10 km northeast of HNR. We selected these variables because they presumably affect the distribution of anglers by influencing their expectations of success (8).

Environmental variables were collected at the time of setting of pop nets to collect fish early life history stages and juveniles. Variables measured were Secchi transparency (m), water temperature (°C), dissolved oxygen (mg/l), specific conductance (μS/cm), salinity (ppm), total dissolved solids (g/l), turbidity (NTU), ph, and dissolved oxygen percent saturation (%). Biological variables used as predictors were CPUE of tilapia and shrimps collected at pop net sites. Thus, 16 variables were compiled for this analysis. In an effort to reduce the dimensionality of the matrix of predictor variables, a principal component analysis (PC-ORD V.4.20; 9) was run, resulting in four significant principal components (broken-stick model; 10) including most of the variables. Thus, all predictor variables were used in the regression analysis.

Canonical correspondence analysis

We used canonical correspondence analysis (CCA) to further examine the association of the 16 variables and the abundance of fishes creeled. The CCA was done in PC-ORD using untransformed variables and fish abundance, with variables standardized to a mean zero and standard deviation of one. The output of CCA includes axes that are orthogonal (uncorrelated) in multivariate space and that can be displayed as a triplot, in which the plotted points for fish taxa and sites can be related to gradients that are represented as arrows. The strength of the correlation of any variable is reflected in the length of the arrow, and its association is reflected in the acuteness of the angle with the axis (i.e., the more acute the angle of arrow, the higher the association with the axis). The triplot is a relational plot in which sites and species that are close together are more alike with regard to any gradient than sites or species that are farther apart; species plotted near sites have higher abundances at those sites. Thus, the relation among species and among sites, and the relation of sites and species to any variables, can be displayed on one plot (11-13).

For this analysis we created a data matrix (main matrix) representing daily creeled fishes, and another data matrix (secondary matrix) representing the same 16 variables used in regression analysis. To try to reduce the dimensionality of the secondary matrix, a PCA was run on it, resulting in four significant principal components including most of the variables. Although some variables were correlated (e.g., salinity with specific conductance and total dissolved solids, Secchi transparency with turbidity), CCA performs well with nonorthogonal and collinear gradients (12). Thus, the full secondary matrix was used in the analysis. For testing significance of the axes, a Monte Carlo test with 5000 randomizations was run. The relative contributions of the different variables to the CCA ordination axes were assessed from their canonical coefficients and intraset correlations.

Results

Regression analysis provided a predictive and quantitative approach for understanding which studied variables were driving fishing success at HNR. Biological, environmental, and meteorological variables were important predictors for explaining variability in fishing success. The best model for each targeted fish is presented in table 1. Two models were single factor regressions; CPUE of small tilapia was highly predictive of snook HPUE, and pH was highly predictive of tilapia HPUE. In both cases the relation was positive, indicating an increase in HPUE with increasing predictor variables. Tarpon HPUE was negatively related to precipitation and positively related to Secchi transparency and CPUE of shrimps. These results suggested that days with no precipitation and high water transparency were conducive to harvest of proportionally more tarpon compared to days with precipitation and turbid waters. Standardized partial regression coefficients suggested that precipitation was as important as Secchi transparency and shrimp CPUE in estimating tarpon HPUE.

As the multiple regression did, the CCA run on fishes also indicated that the HPUEs of snook, tarpon, and tilapia were associated with different gradients. However, CCA identified some additional significant gradients not identified by multiple regression. The first axis was dominated by dissolved oxygen, temperature of the water, precipitation, and pH, whereas precipitation the previous day, Secchi transparency, and turbidity were highly correlated with the second axis (table 2; figure 2). The eigenvalues (first axis= 0.66, second axis= 0.29) showed that the extracted gradients were large (14), indicating that the probability of occurrence of the fish species along the gradients actually

Table 1
Multiple regression models describing harvest-per-unit-effort (HPUE; fish/day) of the three fish species harvested at Humacao Natural Reserve, Puerto Rico, April 2000-March 2001

		Standardized regression coefficient				
Species	Model	b'_1	b'_2	b'_3	r^2	P
Snook	HPUE= 0.031 + 0.056 Tilapia CPUE				0.13	0.050
Tarpon	HPUE= -0.064 - 0.053 PREC + 0.131 ST + 1.7 x 10^{-4} Shrimp CPUE	0.377	0.595	0.433	0.47	0.001
Tilapia	HPUE= -1.074 + 0.163 pH				0.18	0.021

CPUE = catch-per-unit-effort; PREC = precipitation; ST = secchi transparency.

Table 2
Intraset correlations, eigenvalues, and variance explained for the first two axes of canonical correspondence analysis for fish harvest-per-unit-effort (HPUE) and studied variables sampled at Humacao Natural Reserve, Puerto Rico, April 2000-March 2001. The correlations between fish and studied variables, and *P* values for a Monte Carlo test are also shown for the significance of axes

Variable	Axis 1	Axis 2
Precipitation	-0.315	0.044
Precipitation-1	0.235	0.553
Wind	0.112	0.114
Temperature of the air	0.192	-0.209
Barometric pressure	0.037	-0.006
Temperature of the water	0.365	0.055
Dissolved oxygen	-0.401	-0.132
Specific conductance	0.043	-0.197
Salinity	0.006	-0.166
Total dissolved solids	0.095	-0.225
Turbidity	0.303	-0.443
pH	-0.255	-0.135
Dissolved oxygen percent saturation	-0.383	-0.143
Secchi transparency	0.001	0.530
Shrimp CPUE	-0.199	0.350
Tilapia CPUE	0.233	-0.163
Eigenvalue	0.660	0.299
Percentage of variance explained	44.7	20.3
Correlation fish-studied variables	0.868	0.707
	Monte Carlo test	
Axis	Correlation	P
1	0.868	0.038
2	0.707	0.042

Precipitation-1 = precipitation the day previous to the day of creel; CPUE = catch-per-unit-effort.

sampled followed the required unimodal distribution (11). Sixty-five percent of the variance in the species-environmental variables was accounted for by the first two CCA axes. The Monte Carlo permutation test done on CCA axes revealed that correlations between fishes and variables were statistically significant (table 2). Thus, general patterns emerged regarding the fishing success along the gradients identified by the CCA. The first axis separated rainy days with low temperatures and high dissolved oxygen and pH from dry days with high temperatures; and the second axis separated days with high water transparencies from those days with high turbidity. Days with higher precipitation were relatively more successful to harvest tilapia, whereas dry, hot days with high water transparencies yielded high tarpon HPUEs. More snook were harvested in days with high water turbidity.

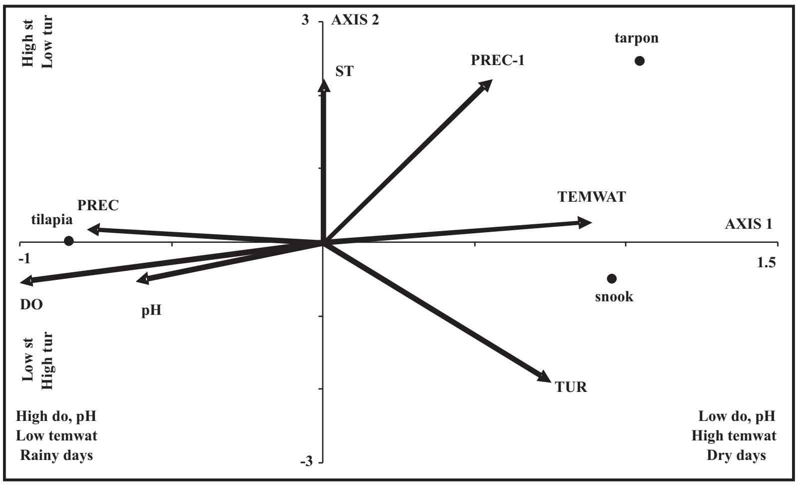

Figure 2. Plot of final scores of fishes and biplot scores of studied variables on the first two canonical axes (Axis 1, Axis 2) for the canonical correspondence analysis on creeled fish samples collected at Humacao Natural Reserve, Puerto Rico, April 2000-March 2001. Arrows indicate direction of increasing value for studied variables. More acute angles between arrow and axis indicate stronger correlation of variables with the axis; e.g., TEMWAT is highly correlated with Axis 1, whereas ST is highly correlated with Axis 2. Fish taxa (filled circles): tarpon= *Megalops atlanticus*; snook = common snook *Centropomus undecimalis*, swordspine snook *C. ensiferus*; tilapia = Mozambique tilapia *Oreochromis mossambicus*, redbreast tilapia *Tilapia rendalli*. Variables (arrows): ST = secchi transparency (m), DO = dissolved oxygen (mg/l), TEMWAT = temperature of the water (°C), TUR = turbidity (NTU), PREC = precipitation, PREC-1 = rain the previous day (cm) (see text for a better description of variables).

Figure 3 shows the distribution of days (grouped by months), in which it can be seen that there was some separation regarding the variables; however, considerable overlap among the months indicated that some of the days within the rainy season had characteristics of the dry season and vice versa. This heterogeneity of day conditions indicated that a fisherman should fish on a day-by-day basis instead of on a month-by-month or season-by-season basis.

Discussion

Many promising new and revised management approaches available for use by managers of small scale fisheries and fishers themselves have emerged in recent years (15). Most of these approaches have become manifest due to coastal marine and freshwater resources collapse as a result of increasing fisheries overexploitation and habitat degradation (15). These collapses constitute serious threats to the alimentary security of millions of people who are dependent upon fisheries for food, income and livelihood. That is why it is increasingly important for the fisheries manager to be creative and innovative; there is no blueprint formula for managing a fishery or an ecosystem: each area or community is different. All this is especially important in the case of small scale fisheries in developing countries (15).

In the past, fishing was less a sport or recreational activity and more a source of food and money than it is now in Humacao. In fact, fishing was the primary source of income in 19th and early 20th centuries in Punta Santiago (the beach district at Humacao) (16). However, since the creation of the HNR

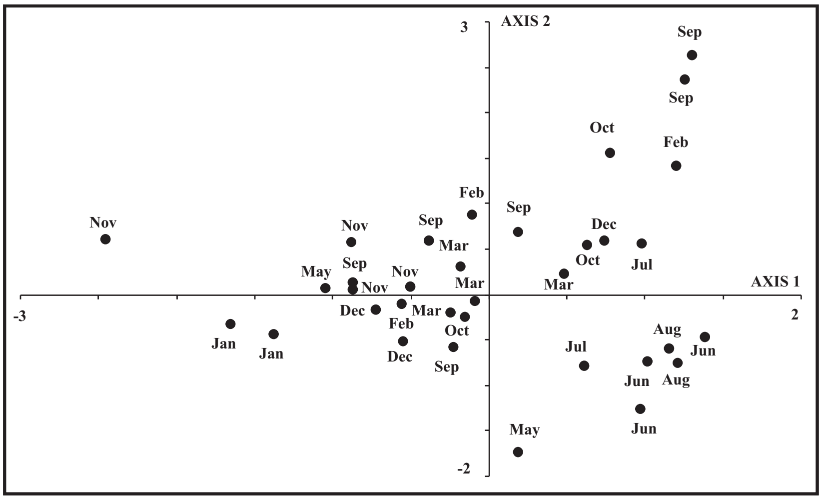

Figure 3. Plot of final scores of creel days (grouped by months) on the first two canonical axes (Axis 1, Axis 2) for the canonical correspondence analysis (CCA) on creeled fish samples collected at Humacao Natural Reserve, Puerto Rico, April 2000-March 2001.

lagoon system, the small-scale fisheries developed there had traditionally been defined as sport or recreational activities (3-4). Today, the HNR lagoon system provides families of the surroundings with unique fishing experiences and other important societal benefits. The HNR lagoon system provides a permanent and affordable source of fish protein, as well as recreational and sport opportunities for important groups of anglers that exploit its fishery resources, and many of them value retaining and eating the catch (4). It was in this sense, and with this mindset, that we executed this research.

Because during the execution of our main research project many sport or recreational anglers asked for recommendations to improve harvesting at HNR, we made an effort to forecast harvest success in the HNR lagoon system. The statistical methods (i.e., multiple regression analysis and CCA) we used to address this objective are currently used in fisheries biology to identify, characterize, and estimate the relation between extrinsic variables and catch rates (8, 17). It has been determined, however, that the success of a fisherman depends, among others, on complex combinations of skill, lures used, and time of year (17). Also, weather conditions can affect fishing as much as fish abundance (18), making fishing success difficult to predict. However, in our study, regression analysis and CCA produced models than can be regarded as satisfactory at least for some fish species, and proved possible to develop models that were amenable to biological, meteorological, and environmental interpretation. In the case of tilapia and snook, regression analysis produced single factor models; tilapia CPUE was positively associated with snook harvest, whereas pH was positively associated with tilapia harvest. For tarpon, regression analysis produced a three-factor model explaining 47% of the variability. Precipitation was negatively associated and Secchi transparency and shrimp CPUE were positively associated with tarpon harvest.

On the other hand, CCA also identified several variables associated with harvest of the principal fishes at HNR. Snook was highly correlated with turbidity whereas tilapia was highly correlated with precipitation. Precipitation the previous day and temperature of the water were highly correlated with tarpon. The relative importance of the environmental variables on tarpon harvest was consistent with some physiological and ecological considerations. It was predictable that temperature would exert strong effects on harvest success because it acts directly on a fish in several ways. For example, temperature governs metabolism and functions as a directive factor eliciting behavioral responses (e.g., movement along gradients) (19). Thus, tarpon were more active and willing to bite lures more frequently at high water temperature. Likewise, tarpon is a top predator relying heavily on vision for prey encounters (20). Thus, presumably tarpon were more active feeding and more likely to bite lures during days with clear waters that in turn were more common in days with no precipitation.

A significant characteristic of this study was the utilization of many data easily gathered or observed by anglers. Temperature of the water, turbidity, pH, and other environmental variables can be easily determined on a daily basis by the reserve's staff and posted in visible sites in the fishing areas, whereas meteorological variables can be obtained routinely from the web page of the National Climatic Data Center and other local servers on the internet. It appears that anglers willing to fish successfully at HNR would benefit from this type of information.

Acknowledgments

We thank Manuel Córbet and the Humacao Natural Reserve personnel for their support during the implementation of this project. We are also indebted with Ramón del Moral and Miguel Ortiz for helping us with much of the fieldwork. Federal Aid Project F-44.1 and La Universidad del Zulia (LUZ), Maracaibo, Estado Zulia, Venezuela provided financial assistance.

References

1. KNOPF R., DRIVER B.L., BASSETT J.R. ***Trans. North Am. Wild. Nat. Res.Conf.*** 38: 191-219, 1973.
2. HUDGINS M.D. ***Trans. Am. Fish. Soc.*** 113: 750-759, 1984.
3. FERRER MONTAÑO O.J. ***Integration of ecological and human components, and management considerations for the fisheries of Humacao Natural Reserve, Puerto Rico***. Ph. D. Dissertation, Mississippi State University, Mississippi State, Mississippi (USA), 105 pp., 2004.
4. FERRER MONTAÑO O.J., DIBBLE E.D., JACKSON D.C., RUNDLE K.R. ***Fish. Res.*** 76: 81-90, 2005.
5. JACKSON D.C., DIBBLE E.D., RUNDLE K.R., FERRER MONTAÑO O.J. ***Fisheries dynamics and management orientations for Humacao Natural Reserve, Puerto Rico.*** Completion Report, Federal Aid Project F-44.1, Department of Wildlife and Fisheries, Mississippi State University, Mississippi (USA), 133 pp., 2001.
6. SAS. ***SAS/STAT Version 8.01***. SAS Institute, Inc., Cary, North Carolina (USA), 1999.
7. HATCHER L., STEPANSKI E. J. ***A step-by-step approach to using the SAS System for univariate and multivariate statistics***. SAS Institute Inc., Books by Users, Cary, North Carolina (USA), 1997.
8. WALSH W.A., KLEIBER P. ***Fish. Res.*** 53: 115-13, 2001.
9. MCCUNE B., MEFFORD M.J. ***Multivariate analysis of ecological data.*** Version 3.15 MJM Software, Gleneden Beach, Oregon (USA), 1997.
10. JACKSON D.A. ***Ecology*** 74: 2204-2214, 1993.
11. TER BRAAK C.J.F. ***Ecology*** 67: 1167-1179, 1986.
12. PALMER M. W. ***Ecology*** 74: 2215-2230, 1993.
13. WAITE I.R., CARPENTER K.D. ***Trans. Am. Fish. Soc.*** 129: 754-770, 2000.
14. GAUCH H. G., STONE E. L. ***Am. Midl. Nat.*** 102: 332-345, 1979.
15. BERKES F., MAHON R., MCCONNEY P., POLLNAC R., POMEROY R. ***Managing small-scale fisheries. Alternative directions and methods***. International Development Research Centre, Ottawa, Ontario (Canada), 183 pp. 2001.

16. U. S. DEPARTMENT OF COMMERCE AND PUERTO RICO DEPARTMENT OF NATURAL AND ENVIRONMENTAL RESOURCES. ***Declaración de impacto ambiental preliminar y plan de manejo para el propuesto segmento de Humacao del sistema nacional para investigaciones estuarinas de Puerto Rico***. Washington D.C. (USA) and San Juan (Puerto Rico), 1986.

17. JACKSON D.C., YE Q. "Riverine fish stock and regional agronomic responses to hydrological and climatic regimes in the upper Yazoo River basin". In: I. G. Cowx (ed.). ***Management and ecology of river fisheries***. Fishing News Books, Blackwell Science, Oxford, UK (USA), pp. 242-257, 2000.

18. U. S. NATIONAL PARK SERVICE. ***Glacier fishing regulations 2002-2003***. U. S. Department of the Interior, Glacier National Park, Montana (USA), 2003.

19. THOMAS M., HAAS R. ***Status of the fisheries in Michigan waters of lake Erie and lake St. Clair 2001***. Michigan Department of Natural Resources, Fisheries Division, Mt. Clemens, Michigan (USA), 2002.

20. FRY F. E.J. "The effects of environmental factors on the physiology of fish". In: W. S. Hoar and D. J. Randall (ed.). ***Fish physiology***. Vol. 6. Academic Press, New York (USA), pp. 1-98, 1971.