Fisheries Management and Ecology

Fisheries Management and Ecology, 2010

A mail survey to estimate the fishery dynamics of southern Florida's bonefish charter fleet

M. F. LARKIN & J. S. AULT

University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL, USA

R. HUMSTON

Washington and Lee University, Lexington, VA, USA

J. LUO

University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami, FL, USA

Abstract Bonefish, *Albula vulpes* (L.), support an economically important recreational fishery in southern Florida, USA that has received little scientific study and has never been adequately assessed. A mail survey of 322 captains that comprise the southern Florida bonefish charter fleet was conducted to acquire a baseline understanding of the primary fishery statistics. The response rate was 59% and a follow-up telephone survey of non-respondents indicated no non-response bias. Experience in the fishery ranged from 3 to 61 years. The annual fishing effort was 30 875 boat days. The majority of the fleet fishing effort occurred in the northern Florida Keys and is presumed to reflect bonefish abundance. The instantaneous mortality rate of released fish was 0.11 year^{-1}. The majority of the respondents indicated that the bonefish stock had declined over the past decade.

KEYWORDS: catch-and-release fishery, direct expenditures, recreational fishing effort, release mortality, stock abundance.

Introduction

Bonefish, *Albula vulpes* (L.), support important recreational fisheries throughout the tropical central western Atlantic Ocean (Colborn *et al.* 2001; Ault 2008). In southern Florida, which includes the Florida Keys, bonefish are primarily found in nearshore waters from Key Biscayne to the Marquesas (Fig. 1), with catches rarely made outside this range. Southern Florida is home to the world's most popular recreational bonefish fishery because of the availability of large bonefish [i.e. >760 mm total length, >4 kg; average fish caught is >563 mm fork length (Larkin *et al.* 2008)]. More than 68% of the saltwater fly rod and saltwater line class world records for bonefish listed by the International Game Fish Association (2009) were caught in southern Florida coastal waters.

Southern Florida has experienced some drastic changes over the years. There have been rapid and substantial growth of both human populations and exploitation from recreational fishing fleets during the past several decades, as well as abrupt environmental changes because of extensive coastal development (Porter & Porter 2002; Ault *et al.* 2005a). Evidence of resource declines and overfishing of important coral reef snapper-grouper fisheries in the Florida Keys has already become apparent (Ault *et al.* 1998, 2005c). Understanding the dynamics of the bonefish population and its southern Florida fishery is paramount to management and conservation of this fishery.

The bonefish fishery is not only experiencing drastic changes but there is also a dearth of scientific knowledge on bonefish biology, ecology and population dynamics; in addition, very little is known about the dynamics of the southern Florida fishery to guide

Correspondence: Michael F. Larkin, University of Miami Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL 33149, USA (e-mail: mlarkin@rsmas.miami.edu)

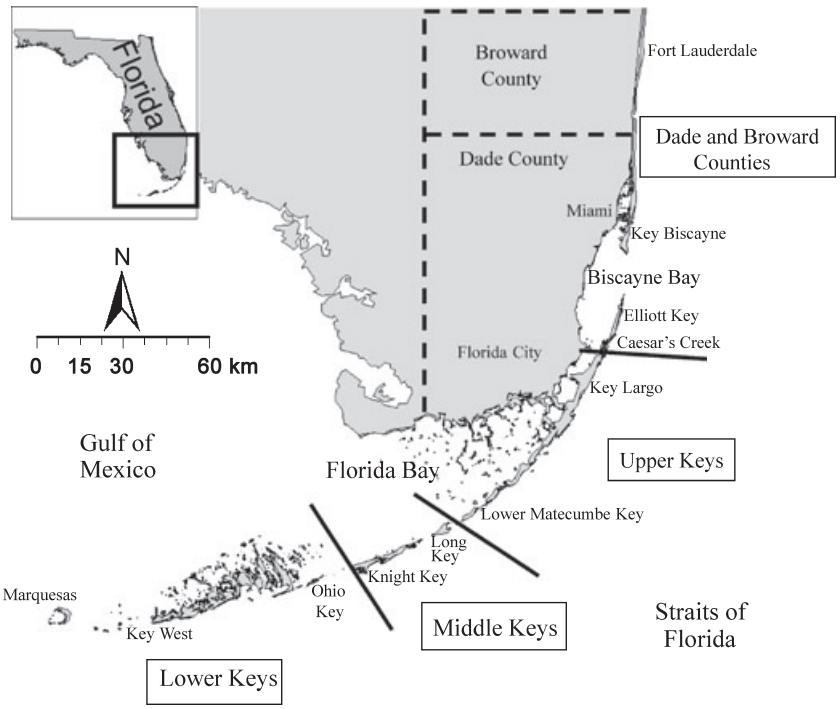

Figure 1. Map of southern Florida illustrating the area over which the bonefish fishery occurs and the geographic regions defined for purpose of analysis.

management strategies (Ault *et al.* 2008a). Because few data on fishery catches and landings have been recorded, interviewing experienced captains about the history and status of the fishery can be an important source of information (Matlock 1991). A survey of the captains was designed to elicit key information on critical issues concerning stock status and fishery dynamics such as number of captains in the bonefish fishery, years in the fishery, fishing effort, annual release mortality rate and changes in stock abundance.

Methods

Survey design

To collect data on southern Florida's bonefish stock and its fishery, a mail survey was designed for captains participating in the bonefish charter fleet who had extensive knowledge of the fish and the fishery. A mail survey was chosen over other survey methods because, on balance, the advantages and disadvantages of mail surveys were the best match for the information sought. Mail surveys are cost-effective, allow anonymity that increases the likelihood of receiving honest responses, allow longer and more complex questions and provide respondents more time to consider questions and provide accurate answers. Disadvantages of mail surveys are that the questionnaire must be easy to understand, they have relatively long completion times and they have the potential for non-response and recall bias. The survey instrument was designed to benefit from the advantages and reduce the disadvantages. This was performed while eliciting information on critical issues such as number of captains in the bonefish fishery, years in the fishery, fishing effort reflecting the total effort units exerted on a stock in a given time period, bonefish mortality rate and perceived changes in stock abundance.

The survey instrument was mailed to individuals that were licensed bonefish captains in southern Florida. The comprehensive sampling frame was compiled from various lists that included: (1) captains that participated in bonefish tournaments held throughout southern Florida; (2) captains with permits to operate charters in Everglades National Park; (3) volunteer captains in the University of Miami's bonefish tagging programme (Humston 2001; Ault *et al.* 2002; Larkin *et al.* 2008; http://www.bonefishresearch.com) and (4) interviews with bonefish captains and tackle vendors throughout southern Florida that subsequently referred us to other bonefish captains.

This was considered to be close to a comprehensive sampling frame.

The survey asked respondents to provide information for an entire year. To reduce recall bias, the survey was mailed at the beginning of the 2002 calendar year (January), which corresponded to the end of the seasonal peak in bonefish fishing effort. Data from an earlier pilot survey suggested a bimodal distribution of annual fishing effort with peaks in the spring (April) and autumn (November) (Humston 2001). To increase response rate, the survey sampling procedure included a three-phased mailing following the 'total design method' outlined by Dillman (1978) and included a raffle with monetary rewards (Goodstadt *et al.* 1977; Pollock *et al.* 1994).

Study site

The southern Florida bonefish charter fleet operates from Key Biscayne in the Upper Florida Keys near Miami, southwestward about 270 km through the Florida Keys, including the eastern side of Florida Bay, to the Marquesas located some 30 km west of Key West (Fig. 1). Except for non-residents, the captains usually maintained primary residence near the location fished. Using primary residence information, the captains were grouped into five regions: (1) Lower Keys (Key West to Ohio Key); (2) Middle Keys (Knight Key to Long Key); (3) Upper Keys (Lower Matecumbe Key to north Key Largo); (4) Dade and Broward Counties (Florida City to Fort Lauderdale); and (5) non-resident, which included captains who did not maintain a primary residence in southern Florida.

Survey instrument

The captains were asked to provide the number of years they had been a captain in southern Florida's bonefish fishery and the number of days in calendar year 2001 spent fishing for bonefish. Previous discussions with captains made it clear that 1 day fishing for bonefish was an 8 h fishing trip. To generate an estimate of total annual effort for the fishery (days yr^{-1}) for 2001, mean annual effort and corresponding 95% confidence intervals (CI) were calculated for each regional stratum, then multiplied by the total number of charter captains for each region to account for non-respondents. Means and confidence intervals were then summed over all strata to obtain total annual effort in the fishery.

To assess the spatial distribution of fishing effort, the survey included a map of southern Florida waters (Biscayne Bay, Florida Bay and Florida Keys) overlain with a grid of 8 km^2 cells. Respondents were asked to shade in the cells where ≥90% or more of their fishing effort occurred and mark an X in cells that contained < 10% (low-effort areas) of their fishing effort for the 2001 calendar year. This information for all the respondents was combined with the responses for total number of days spent fishing for bonefish in calendar year 2001 (TDF_{2001}). This allowed computation of total annual effort for a grid cell (E_i) as

$$E_i = \sum_{i=1}^{n} \left(\frac{0.90}{C_i} \times TDF_{2001} \right) + \left(\frac{0.10}{D_i} \times TDF_{2001} \right) \quad (1)$$

where, C_i is the number of grid cells shaded by respondent i and D_i is the number of grid cells marked with an X by respondent i. The total effort values calculated for each cell were then mapped with a geographic information system (ArcGIS software; Environmental Systems Research Institute, Redlands, CA, USA) to assess the spatial distribution of the bonefish charter fleet for the 2001 calendar year.

Captains were asked to characterise the general physical condition at release of bonefish captured in 2001 as excellent, partially impaired or not likely to survive. Fish in excellent condition displayed no obvious injuries or incapacitation at release. Partially impaired fish were those that sustained minor injury (gut or deep hooking, fin damage, etc.) or required extensive resuscitation (> 5 min) before release. Fish judged not likely to survive were either unable to swim away or were injured or consumed by a predator during capture or after release. Median response values were reported to accommodate the asymmetrical distributions in responses. The captains were asked to rank six factors that affected the likelihood of mortality after release: (1) water temperature; (2) time elapsed in capture; (3) water depth; (4) predator abundance in the area of release; (5) lure or bait used; and (6) hook location.

Non-response bias

Non-response bias was assessed by conducting a phone survey of a randomly selected subsample of mail survey non-respondents. The phone survey used the same questionnaire as the mail survey. Interviews were conducted 3 weeks after the last mailing.

Non-response bias was evaluated in two different ways. For quantitative responses, mean response values were compared between respondent and non-respondent samples using *t*-tests; while multiple choice questions were tested using the likelihood ratio

G-statistic (Sokal & Rohlf 1995). Statistical significance was assessed at $\alpha = 0.05$.

Results

Survey questionnaires were mailed to 322 captains in southern Florida. A total of 190 captains (59%) responded to the mail survey. Captains from the Lower Keys region had the lowest response rate (Table 1). Each respondent answered most of the questions and every question was answered by at least 95% of the respondents.

The fishery

The number of years in the bonefish fishery as a captain ranged from 3 to 61 years ($n = 171$) with a mean ± SE of 22.7 ± 1.0 years. The number of days spent fishing for bonefish during calendar year 2001 ranged from 13 to 250 days with a mean of 97.9 ± 5.1 days. The majority (61%) of the 190 responding captains fished 100 to 150 days yr^{-1}. About 8% of the captains in the fishery focused exclusively on bonefish (≥250 days yr^{-1}) and 31% of the captains fished part-time for bonefish (25 to 50 days yr^{-1}). The 95% CI for days spent fishing for bonefish for the five regions were 65–117 days in the Lower Keys, 112–168 days in the Middle Keys, 83–110 days in the Upper Keys, 52–103 days in Dade & Broward Counties and 0–79 days for non-residents. The 95% CI for total number of days fishing ranged from 24 520 to 37 262 days, with a mean of 30 875 days. Although captains in the Middle Keys expended greater annual effort on average than those from other regions, the majority (53%) of captains resided in the Upper Keys. Therefore, total effort (as number of captains multiplied by average annual effort per captain) was highest overall in the Upper Keys region. This was reflected in spatial distribution of effort over the fishing grounds as indicated by captains (Fig. 2).

Captains reported median values of 90% for bonefish caught in excellent condition, 5% were partially impaired and 0% died ($n = 172$). Median values are reported instead of means because responses were asymmetrically distributed. Because the captains were

Table 1. Survey response details for the five regions of southern Florida

Location	Sample size	Responded	% response
Lower Keys	51	26	51
Middle Keys	37	24	65
Upper Keys	172	95	55
Dade & Broward Counties	53	36	68
Non-resident	9	9	100
Total	322	190	59

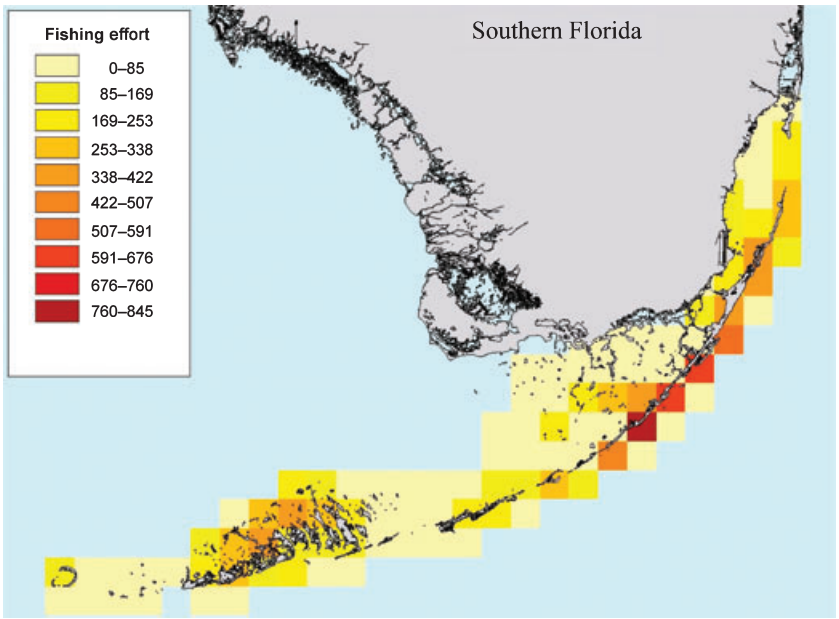

Figure 2. Spatial distribution (8 km^2 cells) of fishing effort for bonefish in 2001 reported by captains of the fishery. Fishing effort was defined as days spent targeting bonefish.

asked to provide an annual estimate of release condition and assuming that the 90% median response represents the expected annual survivorship rate from the fishing event ($S_{release}$), annual release mortality rate ($F_{release}$; $S_{release} = e^{-F_{release}}$) was 0.11.

Although captains indicated that most bonefish were in excellent condition upon release, they suggested that the principal factor contributing to release mortality was predator abundance (mean rank = 2.43, range of 1–6). The next two most important factors were time elapsed during capture (mean rank = 2.64) and hook location (i.e. lip hooked vs gut hooked) (mean rank = 2.84). Seventeen percent of the respondents provided an additional response that indicated that handling time during release was a significant contributor to mortality.

Perceived population abundance changes and anthropogenic impacts

Almost half of the respondents ($n = 83$) indicated the population had declined and 30% of the respondents ($n = 53$) indicated no change in abundance. The respondents that reported a decline most frequently stated that it took place during the past decade. The three most common reasons given for decreased bonefish abundance were increased fishing pressure, increased boating pressure and deteriorating water quality. Seventeen percent of the captains reported increasing bonefish abundance and most stated the trend began about 5 years before 2001. There were differences in responses between captains that had been in the fishery for ≤ 10 years compared with those with >10 years experience (G-test, $P < 0.001$). Captains with less experience responded equally between increased and decreased bonefish abundance. The principal reason given for increased abundance was elimination of entangling (gill) nets in Florida coastal waters commencing in 1995.

Non-response bias

Sixteen non-responding captains were contacted by phone and consented to interviews. Responses of respondents and non-respondents did not differ for years in the fishery ($P = 0.622$), annual days fished for bonefish ($P = 0.731$), condition of bonefish when released ($P = 0.470$) or mean size of bonefish caught in the previous year ($P = 0.093$). Respondents and non-respondents did not differ in their perception of changes in bonefish abundance ($P = 0.062$) or factors affecting mortality ($P = 0.488$). There was no evidence of non-response bias.

Discussion

Information on southern Florida's bonefish fishery was non-existent before this survey. A great amount of research effort was expended to develop a sampling frame for the survey. With a sampling frame established, the next step was to determine the best method to survey the captains. A mail survey was chosen over other methods because of funding constraints and contact method. A telephone survey of the entire fleet could have been completed faster but would have been expensive ($>$ US$1000) and time-consuming compared with a mail survey ($<$ $200). An on-site survey would not have been practical because of the cost and the multiple access sites of the fishery. A mail survey, despite being the most economical survey method in this case, has limitations. Mail surveys tend to have lower response rates and increase the potential for non-response bias (Pollock *et al.* 1994); this was addressed here with a follow-up telephone survey of non-respondents. Cost and time demands limited the sample size of the phone survey and may have restricted the ability to detect differences between respondents and non-respondents. Nevertheless, no non-response bias was detected. Another potential problem with any after-the-fact survey is recall bias. Recall bias of the responses was considered during development of the questionnaire and limited the number and type of questions asked. For example, despite the importance of determining the annual catch of the fishery, this question was not asked because of the likelihood of recall bias. Instead, the survey focused on collecting information that minimised recall bias. The two results that had the greatest potential for recall bias were the condition of bonefish at release and fishing effort for the previous year. Recall bias for these two questions was assumed to be low for several reasons: (1) the captains are attentive to the survival of bonefish during release because their future income depends on the availability of bonefish; (2) they can provide a reliable estimate of the distribution of their fishing effort because they are very familiar with the fishing grounds; and (3) they track the number of days fished for bonefish because it related to their income. Anglers asked to recall fishing activity tend to overestimate the number of days fished (Hiett & Worrall 1977; Gems *et al.* 1982; Chu *et al.* 1992). Although the bonefish captains surveyed were expected to keep records of fishing activity and to have used those records to complete the survey, the accuracy of this information remains unknown.

Annual fishing effort for bonefish appeared to be focused from Biscayne Bay to the Upper Keys. The

highest numbers of bonefish captains also resided close to these areas suggesting that the captains lived close to best fishing locations. If fishing effort was assumed to be concentrated in areas of high stock abundance, then the majority of Florida's bonefish stock is likely located in the northern Florida Keys (Dade County and Upper Keys). The fishing effort could have been influenced by spatial variation in the size of bonefish available in the different areas instead of bonefish abundance, but three annual bonefish visual surveys in southern Florida (Ault *et al.* 2008b) revealed that the fishing effort values significantly related to bonefish abundance.

Captains stated that 90% of the bonefish were released in excellent condition. Thus, the 10% in less than excellent condition were assumed mortalities. This mortality estimate was lower than the mean mortality rate presented in a compilation of marine catch-and-release fisheries by Bartholomew and Bohnsack (2005) and the 39% and 42% reported for bonefish caught and released at two sites in the Bahamas by Cooke and Philipp (2004). Fishing mortality in the south Florida bonefish fishery is relatively low, but bonefish are relatively long lived (19 years; Crabtree *et al.* 1996). Thus, even relatively low mortality in this catch-and-release fishery may reduce stock abundance.

The captains ranked predator abundance, duration of capture and hook location as the three most important variables contributing to bonefish mortality. This suggests that post-release survival can be increased if captains are willing to: (1) avoid fishing in locations with high predator abundance (as suggested by Cooke & Philipp 2004); (2) use high-breaking strength fishing lines (>4.5 kg) to reduce capture time; and (3) use hooks that decrease the probability of 'gut-hooking' fish (e.g. circle hooks).

The 322 charter captains targeted bonefish for about 30 875 days a year at a fee of $400 a day. This produced a direct expenditure of US$12 million for 2001. Despite the economic impact of the charter-based recreational fishery, there are no survey programmes in place to monitor it effectively. Landings and catch statistics of southern Florida's bonefish fishery have been recorded by the Marine Recreational Fisheries Statistics Survey (MRFSS), but this survey did not effectively sample bonefish fishery participants. For example, this mail survey results indicate that annual effort among charter captains in 2001 was approximately 30 875 days targeting bonefish. However, the MRFSS results for 2001 estimated the number of days (angler trips in their database) fishing for bonefish from the charter fleet was 14 334 for Dade and Monroe (Florida Keys) counties (unpublished data from the National Marine Fisheries Service, Fisheries Statistics Division, http://www.st.nmfs.noaa.gov). Also, MRFSS reported no bonefish catches in the years of 2002, 2004, 2005 and 2006, despite a bonefish tagging project in southern Florida having at least 500 bonefish tagged in each of those years (Larkin *et al.* 2008). The erroneous estimates of fishing effort and catch by the MRFSS method could be due to the bonefish fishery having many access locations, and the high likelihood that the limited sampling locations of the MRFSS survey method would have failed to intercept the bonefish captains. Flaws in the MRFSS sampling, such as those discussed above, were noted in a National Research Council (2006) study.

This survey collected information only from the bonefish charter captain fleet. The fishing effort of the bonefish recreational fleet should be addressed. Leeworthy (1996) and Leeworthy and Wiley (1997) estimated effort of all the recreational activities (fishing, diving, boating, etc.) in the Florida Keys. These surveys were very broad in scope and grouped the nearshore fishing fleet into one. This fleet is composed of fishers not only targeting bonefish but several other species such as red drum, *Sciaenops occelatus* (L.), snook, *Centropomus undecimalis* Bloch, spotted seatrout, *Cynoscion nebulosus* Cuvier, and many more species. The proportion of fishing effort in the nearshore fishery targeting bonefish relative to other species is unknown. Therefore, recreational (non-captain) fishing effort in the bonefish fishery cannot be reliably determined.

This mail survey was the first to mine the extensive knowledge of experienced charter captains and gather substantial information on the southern Florida bonefish fishery. This group of fishers probably spends more time on the water in bonefish habitats then any other fishers or even scientists. Their knowledge has helped to fill important knowledge gaps for this fishery. This survey also documents that the majority of the anecdotal evidence suggests a decline in the Florida bonefish stock. These survey results need to be validated with other data sources and can be used to trigger a scientifically valid assessment of the resource. To date, the only fishery regulations in place prohibit commercial harvests and limit recreational harvests to one fish greater than 457 mm TL per angler per day (Florida Fish and Wildlife Conservation Commission 2009). These limited regulations may be inadequate to ensure future sustainability of the fishery given the increases in angling effort and regional environmental changes.

The survey not only provided useful information for fishery management, but also allowed researchers to develop a trusted presence and rapport within the

community of bonefish captains. This relationship has paved the way for further cooperative scientist–captain efforts on other bonefish research including mark–recapture, acoustic telemetry and visual surveys of bonefish in southern Florida (Ault *et al*. 2005b; Ault 2008; Humston *et al*. 2008; Larkin *et al*. 2008). Knowledge gained from working collaboratively with bonefish captains may help facilitate development of cooperative management strategies to conserve and sustain southern Florida's ecologically and economically important bonefish resource.

Acknowledgments

This research was supported by funding from the Bonefish and Tarpon Trust, Sanctuary Friends Foundation of the Florida Keys, National Fish and Wildlife Foundation Challenge Grants No. 2001-0078-00-SC and 2004-0050-000, and the National Park Service Cooperative Ecosystems Studies Unit Grant H500000B494. A Ryan Kelley Memorial Scholarship to MFL from the International Women's Fishing Association is also gratefully acknowledged. We thank Captains Bill Curtis and the late Joel Kalman for their assistance in the development of the survey instrument; Brain Forist and Gary Machlis of the National Park Service and Bob Leeworthy of NOAA Office of National Marine Sanctuaries for their sage advice on the final instrument; and the Florida Keys Fishing Guides Association for their continued interest and cooperation in our research efforts. We thank Natalia Zurcher, Nick Farmer, Anya Barranco, and Lisa Kamin for technical assistance.

References

Ault J.S. (ed.) (2008) *Biology and Management of the World Tarpon and Bonefish Fisheries*. Boca Raton, FL: Taylor and Francis Group. CRC Series on Marine Biology. 441 pp.

Ault J.S., Bohnsack J.A. & Meester G.A. (1998) A retrospective assessment of multispecies coral reef fish stocks in the Florida Keys. *Fishery Bulletin* **96,** 395–414.

Ault J.S., Humston R., Larkin M.F. & Luo J. (2002) *Development of a Bonefish Conservation Program in South Florida*. Final Report to the National Fish and Wildlife Foundation on Challenge Grant No. 2001007800-SC. Washington, DC: National Fish and Wildlife Foundation. 103 pp. Available at: http://www.nfwf.org.

Ault J.S., Bohnsack J.A., Smith S.G. & Luo J. (2005a) Towards sustainable multispecies fisheries in the Florida, USA coral reef ecosystem. *Bulletin of Marine Science* **76,** 595–622.

Ault J.S., Larkin M.F., Luo J. & Zurcher N. (2005b) *Bonefish-tarpon Conservation Research Program*. Final Report to National Fish & Wildlife Foundation on Challenge Grant No. 2004-0050-000. Washington, DC: National Fish and Wildlife Foundation. 121 pp. Available at: http://www.nfwf.org.

Ault J.S., Smith S.G. & Bohnsack J.A. (2005c) Evaluation of average length as an indicator of exploitation status for the Florida coral reef fish community. *ICES Journal of Marine Science* **62,** 417–423.

Ault J.S., Humston R., Larkin M.F., Perusquia E., Farmer N.A., Luo J., Zurcher N., Smith S.G., Barbieri L.R. & Posada J.M. (2008a) Population dynamics and resource ecology of Atlantic tarpon and bonefish. In: J.S. Ault (ed.) *Biology and Management of the World Tarpon and Bonefish Fisheries*. Boca Raton, FL: Taylor and Francis Group. CRC Series on Marine Biology, pp. 217–258.

Ault J.S., Moret S., Luo J., Larkin M.F., Zurcher N. & Smith S.G. (2008b) Florida Keys bonefish population census. In: J.S. Ault (ed.) *Biology and Management of the World Tarpon and Bonefish Fisheries*. Boca Raton, FL: Taylor and Francis Group. CRC Series on Marine Biology, pp. 383–398.

Bartholomew A. & Bohnsack J.A. (2005) A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries* **15,** 129–154.

Chu A., Eisenhower D., Hay M., Morganstein D., Neter J. & Waksberg J. (1992) Measuring the recall error in self-reported fishing and hunting activities. *Journal of Official Statistics* **8,** 19–39.

Colborn J., Crabtree R.E., Shaklee J.B., Pfeiler E. & Bowen B.W. (2001) The evolutionary enigma of bonefishes (*Albula* spp.): cryptic species and ancient separations in a globally distributed shorefish. *Evolution* **55,** 807–820.

Cooke S.J. & Philipp D.P. (2004) Behavior and mortality of caught-and-released bonefish (*Albula* spp.) in Bahamian waters with implications for a sustainable recreational fishery. *Biological Conservation* **118,** 599–607.

Crabtree R.E., Harnden C.W., Snodgrass D. & Stevens C. (1996) Age, growth, and mortality of bonefish, *Albula vulpes*, from the waters of the Florida Keys. *Fishery Bulletin* **94,** 442–451.

Dillman D.A. (1978) *Mail and Telephone Surveys: The Total Design Method*. New York: Wiley, 344 pp.

Florida Fish and Wildlife Conservation Commission. (2009) *Florida Fishing Regulations: Saltwater Edition*. Tallahassee, FL: Division of Marine Fisheries Management. 6 pp. Available at: http://www.floridaconservation.org.

Gems B., Ghosh D. & Hitlin R. (1982) A recall experiment Impact of time on recall of recreational fishing trips. *Proceedings of the Section on Survey Research Methods*, Washington, DC: American Statistical Association, pp. 372–375.

Goodstadt M.S., Chung L., Kronitz R. & Cook J. (1977) Mail survey response rate: their manipulation and impact. *Journal of Marketing Research* **14,** 391–395.

Hiett R.L. & Worrall J.W. (1977) *Marine Recreational Fishermen's Ability to Estimate Catch and to Recall Catch and Effort over Time*. Research report HSR-RR/13-CD. McClean, VA: Human Sciences Research, Inc. 22 pp.

Humston R. (2001) *Development of Movement Models to Assess the Spatial Dynamics of Marine Fish Populations*. PhD Dissertation, Coral Gables, FL: University of Miami, 256 pp.

Humston R., Ault J.S., Schratwieser J., Larkin M.F. & Luo J. (2008) Incorporating user-group expertise in bonefish and tarpon fishery research to support science-based management decision making. In: J.S. Ault (ed.) *Biology and Management of the World Tarpon and Bonefish Fisheries*. Boca Raton, FL: Taylor and Francis Group. CRC Series on Marine Biology, pp. 419–428.

International Game Fish Association. (2009) *World Record Game Fishes: Freshwater, Saltwater, and Flyfishing*. Dania Beach, FL: International Game Fish Association. 408 pp.

Larkin M.F., Ault J.S., Humston R., Luo J. & Zurcher N. (2008) Tagging of bonefish in south Florida to study population movements and stock dynamics. In: J.S. Ault (ed.) *Biology and Management of the World Tarpon and Bonefish Fisheries*. Boca Raton, FL: Taylor and Francis Group. CRC Series on Marine Biology, pp. 301–320.

Leeworthy V.R. (1996) *Technical Appendix: Sampling Methodologies and Estimation Methods Applied to the Florida Keys/Key West Visitor Surveys*. Silver Spring, MD: NOAA SEA Division. 170 pp.

Leeworthy V.R. & Wiley P.C. (1997) *A Socioeconomic Analysis of the Recreation Activities of Monroe County Residents in the Florida Keys/Key West*. Silver Spring, MD: NOAA SEA Division. 49 pp.

Matlock G.C. (1991) Use of surveys in decision making. In: D. Guthrie, J.M. Hoenig, M. Holliday, C.M. Jones, M.J. Mills, S.A. Moberly, K.H. Pollock & D.R. Talhelm (eds) *Creel and Angler Surveys in Fisheries Management*. Bethesda, MD: American Fisheries Society, pp. 1–4.

National Research Council. (2006) *Review of Recreational Fisheries Survey Methods*. Washington, DC: National Academies Press. 202 pp.

Pollock K.H., Jones C.M. & Brown T.L. (1994) *Angler Survey Methods and Their Applications in Fisheries Management*. Bethesda, MD: American Fisheries Society. 371 pp.

Porter J.W. & Porter K.G. (eds) (2002) *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys*. Boca Raton, FL: CRC Press, 1000 pp.

Sokal R.R. & Rohlf F.J. (1995) *Biometry: The Principles and Practice of Statistics in Biological Research*, 3rd edn. New York: W. H. Freeman and Company, 887 pp.