

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Publications, Agencies and Staff of the U.S.
Department of Commerce

U.S. Department of Commerce

2015

Fisher and diver perceptions of coral reef degradation and implications for sustainable management

Ayana Elizabeth Johnson

University of California, San Diego, ayana@waittinstitute.org

Jeremy B.C. Jackson

University of California, San Diego

Follow this and additional works at: <http://digitalcommons.unl.edu/usdeptcommercepub>

Johnson, Ayana Elizabeth and Jackson, Jeremy B.C., "Fisher and diver perceptions of coral reef degradation and implications for sustainable management" (2015). *Publications, Agencies and Staff of the U.S. Department of Commerce*. 550.

<http://digitalcommons.unl.edu/usdeptcommercepub/550>

This Article is brought to you for free and open access by the U.S. Department of Commerce at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Publications, Agencies and Staff of the U.S. Department of Commerce by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.



Contents lists available at ScienceDirect

Global Ecology and Conservation

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

Original research article

Fisher and diver perceptions of coral reef degradation and implications for sustainable management

Ayana Elizabeth Johnson^{a,b,*}, Jeremy B.C. Jackson^{a,c,d}^a Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92083-0202, USA^b Waitt Institute, 1201 Connecticut Ave. NW, Floor 3, Washington, DC 20036, USA^c Department of Paleobiology, National Museum of Natural History, PO Box 37012, Washington, DC, USA^d International Union for Conservation of Nature, 1630 Connecticut Ave. NW, 3rd Floor, Washington, DC, 20009, USA

HIGHLIGHTS

- We interviewed fishers and divers on extent and causes of reef degradation.
- Fishers know fish are severely depleted. Divers consider the reefs healthy.
- Fishers and divers differ in perceptions of causes and remedies for decline.
- Most fishers and divers support more management of both fishing and diving.
- The social climate is ripe for balanced restrictions on reef use.

ARTICLE INFO

Article history:

Received 9 January 2015

Received in revised form 3 April 2015

Accepted 4 April 2015

Available online 17 April 2015

Keywords:

Artisanal fishing

SCUBA diving

Coral reefs

Reef management

Resource degradation

Shifting baselines

ABSTRACT

Fishers and divers are the major resource users of Caribbean coral reefs. On Curaçao and Bonaire, reef condition is good relative to the Caribbean average, but fishes and corals have greatly declined over the last few decades. We interviewed 177 fishers and 211 professional SCUBA divers to assess their views on the extent and causes of degradation. Fishers know fish stocks are severely depleted and declining, whereas divers were aware of declines but had “shifted baselines” and consider the reefs healthy. Fishers and divers differ in perceptions of the causes and appropriate remedies for decline. Fishers generally blame external factors such as changes in climate, currents, or industrial fishing offshore, whereas divers primarily blame overfishing and coastal development. Nevertheless, the great majority of both fishers and divers support more management of both fishing and diving. Thus the social climate is ripe for balanced and strong restrictions on both groups for reef recovery and sustainable use. Exclusion of both fishers and divers from protected areas of significant size around the islands would be a major step forward towards the long-term conservation of reef resources.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Caribbean reefs are severely degraded due to overfishing, coastal development, pollution, and climate change (Jackson, 1997; Hughes et al., 2003; Pandolfi et al., 2005; Jackson et al., 2014). However, building stakeholder support for managing

* Corresponding author at: Waitt Institute, 1201 Connecticut Ave. NW, Floor 3, Washington, DC 20036, USA.

E-mail address: ayana@waittinstitute.org (A.E. Johnson).

<http://dx.doi.org/10.1016/j.gecco.2015.04.004>

2351-9894/© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

human impacts is hindered by ignorance of the severity of degradation relative to pristine conditions. This is the problem of “shifting baselines” that plagues understanding of all forms of environmental change, lowering our standards for what healthy ecosystems look like (Pauly, 1995; Jackson et al., 2011).

Shifting baselines are a problem for industrial fisheries because catch limits are set based upon modern scientific data obtained long after fishing began. Similar problems exist in artisanal fishing communities; more experienced fishers usually consider a greater number of species depleted, note earlier dates for the onset of depletion, and are more likely than less-experienced fishers to notice species declines (Sáenz-Arroyo et al., 2005; Ainsworth et al., 2008; Bunce et al., 2008; Godoy et al., 2010). Few scientists or recreational divers have ever seen a healthy reef and have little basis for understanding the effects of coastal development and tourism, such as damage to corals by divers (Hawkins et al., 1999; Barker and Roberts, 2004).

Here we use the Caribbean islands of Curaçao and Bonaire as a case study to explore stakeholders’ perceptions of reef fish populations and reef health, and to inform future management. Through extensive interviews of artisanal fishers and professional SCUBA divers, we identified the effects of age, profession, island of residence, and years of experience on (1) expectations for abundance; (2) perceived causes of changes in fish abundance and reef condition; and (3) support for management measures. To our knowledge, this is the first comparative study on the ecological baselines of fishers and divers.

1.1. Local history of fishing and diving and coral reefs

Research was conducted in 2009 and 2010 when Curaçao’s resident population was approximately 142,000 versus 13,400 on Bonaire (Central Bureau of Statistics, 2010). Artisanal fishing has occurred on both islands for several hundred years without industrialized fishing or significant exportation. Dive tourism began on both islands in the 1960s. Tourism is the primary economic activity on both islands, especially on Bonaire whose economy is largely dependent on recreational diving (Bouchon et al., 2008). Approximately 44% of Bonaire’s tourists buy tags that allow them to dive (over 31,000 tags sold in 2010; Tourism Corporation Bonaire, 2011). Comparable data are unavailable for Curaçao.

The number of fishers on Curaçao has declined from 652 in 1959 (Zaneveld, 1961), to 390 in 1994 (Dilrosun, 2001), to about 200 today (50 full-time and 150 part-time). There are around 30 full-time and 50 part-time fishers on Bonaire; historical numbers are unavailable but anecdotal evidence suggests a several fold decrease. The fishers are largely owner-operators, or working in small groups of one to three crew with a captain. There are around 130 professional SCUBA divers on Curaçao and 120 on Bonaire, spread amongst approximately 40 dive shops.

Average Caribbean coral cover has declined from 35% to 16% since 1970 (Jackson et al., 2014). Coral cover in Curaçao and Bonaire is approximately double this modern Caribbean average but has declined markedly. Fish data are limited but most Caribbean reefs are severely overfished. Wells (1988) reported “overfishing, especially illegal spearfishing,” in Curaçao, versus Bonaire where large fish were “far more abundant,” and “lacking signs of over-exploitation.” More recently, mean fish biomass on the two islands was estimated at 135 g/m², with higher values on Bonaire than Curaçao (Sandin et al., 2008; M. Vermeij pers. comm.). Less than 7% of the biomass was apex predators, and no sharks were observed (Sandin et al., 2008). Spearfishing caused sharp declines in parrotfish populations, although Bonaire banned take of parrotfish in 2010 (Steneck et al., 2011). For context, Caribbean fish biomass ranges from as little as 15 g/m² in Jamaica to nearly 600 g/m² in Cozumel (Newman et al., 2006), with large groupers and snappers virtually absent, and most reefs dominated by smaller species (Pandolfi et al., 2003; Jackson et al., 2014).

Anecdotes from interviewed fishers and divers echo the scientific evidence for sharp declines in fish since the 1980s. In variations on a theme, interviewees express how “the coast is a desert now” compared to what they observed or to stories they have heard. Spear fishers reported having behaved as if “the reef was a supermarket,” choosing what they wanted, and catching goliath groupers almost their own size (Fig. 1(a)), or a half dozen Nassau and other groupers (Fig. 1(b)). Large groupers are now rare, spearfishers’ catches are dominated by parrotfish (Fig. 1(c)), and two experienced spearfishers using SCUBA were unable to catch a single large grouper or snapper in two dives (Fig. 1(d); A.E.J. pers. obs.). The shift to targeting parrotfish is of particular concern because of their role cleaning the reef of macroalgae that suppress coral recruitment, growth, and survival (Jackson et al., 2014).

Records of hook-and-line catches tell a similar story. In the 1950s, a line fisher in nearshore waters would typically catch 9 to 23 kg of mostly large groupers and snappers (Zaneveld, 1961), but by 1995, 75% of fishers on Curaçao reported catching less than 5 kg per day (unpublished appendix to Debrot and Nagelkerken, 2000). By 2001 the average was down to approximately 4 kg per day (Dilrosun, 2001). There are no time series data of catch landings on either Curaçao or Bonaire.

2. Methods

In the fall of 2009 on Curaçao and in the spring of 2010 on Bonaire, the first author interviewed 177 full-time and part-time fishers, and 211 professional SCUBA divers, including dive instructors, dive masters, and dive guides. All fishing there can be considered small-scale or artisanal (there is no large-scale industrial fishing or exportation of fish), so here we consider all interviewed fishers as a single group. English–Papiamentu–Dutch translators were used for all fisher interviews, but were unnecessary for divers who all spoke English.

Lack of comprehensive lists of fishers and divers precluded stratified random sampling, so considerable effort was made to include fishers at every port and divers at every shop, to interview fishers and divers of all ages, and to conduct as

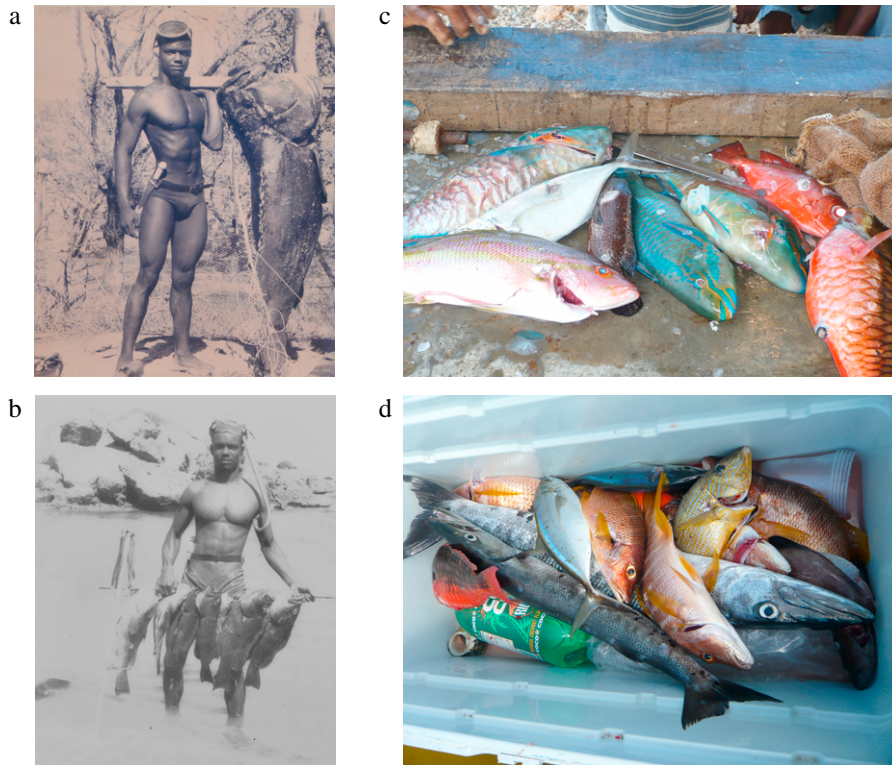


Fig. 1. Catch of spearfisher Jose Streder in Curaçao in 1960, (a) a goliath grouper and (b) Nassau and other groupers; and a day's catch in 2009 (c) for one fisher using snorkel (mostly parrotfish) and (d) for two fishers using SCUBA.

many interviews as possible. AEJ presented herself as a neutral researcher, unaffiliated with any local group, interested in understanding uses and perceptions of coral reefs and fisheries. At the end of each interview, contact information for additional fishers and divers was requested, in what is termed a snowball sampling strategy (Bernard, 1994).

We acknowledge the possible influence of interviewee wariness of and discomfort about being interviewed. AEJ attempted to combat these effects by (1) letting interviewees set the time and location of interviews to maximize their comfort and convenience, (2) showing photographs of fish (use of images can increase openness and trigger memories; Collier, 1957), (3) using bi-culturally savvy local translators, and (4) conducting interviews in a conversational and casual manner. Interviewees were positively engaged: most gave more detailed responses than requested, none stopped without completing the full interview, many shared fishing and diving stories beyond what was asked, and several later approached AEJ to offer additional information they had forgotten to mention.

Interview questions spanned fishing and diving practices, reef and fisheries status and trends, marine resource management, and demographics. Responses to the questions focused on perceptions of reef resources are presented here (see Appendix A1 for question list). Fishers were questioned about what they catch, and divers were questioned about what they see underwater. Both groups were asked how coral reefs should be managed, including fishing gear restrictions and marine reserves.

We used nine questions about gears and seven questions about reserves to calculate gear scores and reserves scores for each interviewee based on percentage of restrictions they supported. For example, a diver's response that she supported banning use of gill nets would earn one point, whereas a response that she did not would receive zero points, and supporting seven out of nine gear restrictions would earn a score of 77.8. We used responses to these questions about gear and reserves, plus five miscellaneous management questions (i.e., limiting the number of fishers or divers, banning anchoring, banning catch of juveniles, and banning catch of particular species), to calculate an overall conservation score. The highest possible score is 100 (supported all twenty-one restrictions) and the lowest is zero (opposed to all restrictions).

We created a baseline score from responses to questions used to understand interviewees' ecological baselines. For each question, points were based on level of awareness of ecosystem degradation the responses implied. For example, a fisher's response that he catches smaller fish than did previous generations of fishers would earn one point, whereas a response that fish size is the same would earn 0.5, and a response that fish size is bigger would earn zero points. The maximum and minimum possible scores were 7 and zero, with 7 representing an un-shifted baseline. This scoring assumes that fish populations and reef health have been in decline over the last decade, a fact strongly supported by all available evidence.

Fishers and divers were categorized by age: youngest (15–30 years of age), young (31–45), middle (46–60), and old (61–81 years). Altering these age group definitions a few years in either direction did not change patterns of results.

Table 1

Means, with standard errors in parentheses, for demographic information for fishers and divers interviewed on Curaçao and Bonaire.

	Fishers			Divers		
	Curaçao	Bonaire	Overall	Curaçao	Bonaire	Overall
Number of interviewees	126	51	177	112	99	211
Youngest (15–30)	13	13	26	45	32	77
Young (31–45)	34	5	39	52	30	82
Middle (46–60)	58	16	74	13	31	44
Old (61–81)	21	17	38	2	6	8
Mean age	48.6 (1.18)	51.0 (2.71)	49.2 (1.15)	34.3 (0.87)	39.7 (1.23)	36.8 (0.76)
Mean age started fishing or diving	13.7 (0.65)	10.1 (0.92)	12.6 (0.54)	21.9 (0.71)	22.5 (0.92)	22.3 (0.57)
Mean year started fishing or diving	1975 (1.21)	1969 (2.61)	1973 (1.16)	1997 (0.83)	1993 (1.17)	1994 (0.71)
Mean generations of fishers or divers in family	3.0 (0.14)	3.4 (0.17)	3.1 (0.11)	1.3 (0.55)	1.4 (0.53)	1.3 (0.04)
Mean years fishing or diving	34.6 (1.21)	40.8 (2.61)	36.6 (1.16)	12.4 (0.82)	17.0 (1.12)	14.6 (0.70)
Mean years local diving				7.1 (0.09)	10.1 (0.95)	8.5 (0.66)
Mean fishing days per week	3.6 (0.24)	3.8 (0.27)	3.7 (0.17)			
Mean dives per week				8.1 (0.48)	6.2 (0.40)	7.2 (0.33)

Since there are few professional divers over 60, middle-aged and old divers were combined for analysis. Divers were also categorized by local diving experience (<1 year, 1–4 years, 5–10 years, and >10 years of diving on that island), and by total diving experience (<10 years, 10–19 years, and ≥20 years of global lifetime dive experience). Fishers were categorized by total years of experience (<10 years, 10–19 years, 20–29 years, 30–39 years, and >40 years).

We compared survey responses between islands and professions, and among age groups and years of experience. For categorical response variables, we used χ^2 goodness-of-fit-tests, and where sample sizes were small Fisher's exact tests. For continuous response variables, such as demographic data and best or worst year of fishing, we used one-way analysis of variance (ANOVA).

3. Results

3.1. Interviewee demographics and experience

The 388 interviews involved an estimated 63% of fishers on Curaçao, 65% of fishers on Bonaire, 86% of professional divers on Curaçao, and 83% of professional divers on Bonaire. Interviewed fishers were significantly older than divers (Table 1; statistics for all comparisons are provided in Table 2). Fishers had more experience than divers whether measured in starting age, starting year, or years of experience. Divers on Bonaire had more diving experience than those on Curaçao, both overall and locally. Fishers' families have been fishing for a mean of 3.1 generations, longer than the mean of 1.3 generations for divers. First generation professionals comprised 69% of interviewed divers, compared to only 18% for fishers. Of interviewees with children, only 17% of fishers versus 53% of divers wanted their children to follow in their profession. Just 53% of fishers and 44% of divers considered their profession profitable, and of those who did, about one-third expected that profitability would only last another 10 years or less.

3.2. Fish catch quantity, abundance, and size

Most fishers (89%) perceived catching fewer fish than previous generations, with no differences in responses between islands, age groups, or years of experience (Fig. 2(a)). Of the few fishers who reported stable catch quantity, two added caveats that they now have a larger boat, go further offshore, and have more advanced gear such as fish finders. Four fishers noted catching less despite better equipment. In contrast, most divers (77%) responded that local fish populations were of average or greater abundance compared to what they would expect a healthy coral reef fish population should look like, with no effect of age group, island or local experience (Fig. 2(d)). Divers on Bonaire were more likely than those on Curaçao to rate their local fish populations as abundant or very abundant (55% versus 33%).

Interviewees with over five years of experience were asked to compare current fish catch ($N = 171$ fishers) or population size ($N = 111$ divers) to five years prior. More fishers than divers (65% versus 45%) reported a decrease. Younger and less experienced fishers and divers were less likely to report declines. Divers on Curaçao with more than 10 years of local experience ($N = 26$) were more likely to have perceived a decrease than divers with shorter local experience (60% versus 21%). No diver on either island with over 20 years of local experience believed the fish population had increased in the last five years ($N = 27$).

Table 2

Statistics for all reported significant differences between groups of interviewees.

Comparison	Statistic
Fishers (compared to divers; Table 1, Fig. 2)	
Older	$F_{1,385} = 84.9, p < 0.0001$
Started younger	$F_{1,381} = 148.4, p < 0.0001$
Started in an earlier year	$F_{1,382} = 284.3, p < 0.0001$
More years of experience	$F_{1,382} = 287.0, p < 0.0001$
More generations of their profession in their family	$F_{1,379} = 271.5, p < 0.0001$
Less likely to want their children to have their profession	$\chi^2 = 26.9, p < 0.0001$
More likely to report a decrease in fish	$\chi^2 = 16.0, p < 0.0001$
More likely to perceive fewer fish compared to 10 years ago	$\chi^2 = 15.0, p = 0.001$
Younger and less experienced fishers (compared to older and more experienced)	
More likely to report recent years fishing as their best	$F_{3,147} = 11.3, F_{3,122} = 9.1, \text{ both } p < 0.0001$
Less likely to report declines in catch	$\chi^2 = 19.8 \text{ and } \chi^2 = 15.49, \text{ both } p < 0.02$
Divers on Bonaire (relative to Curaçao; Table 1, Fig. 2.)	
More years of diving experience	$F_{1,208} = 11.2, p = 0.001$
More years of local diving experience	$F_{1,208} = 5.74, p = 0.017$
More likely to rate fish populations as abundant or very abundant	$\chi^2 = 17.4, p = 0.002$
More likely to have abandoned some dive sites	$\chi^2 = 13.7, p < 0.0001$
Divers on Curaçao (but not Bonaire)	
If more local experience, more likely abandoned sites	$\chi^2 = 12.7, p = 0.005$
If local experience ≥ 10 years, more likely perceived a decrease in fish	$\chi^2 = 13.9, p = 0.031$
Remarks on the absence or decline of large fish more frequently made by	
Divers on Bonaire than Curaçao	$\chi^2 = 14.8, p < 0.0001$
Divers with more experience	$\chi^2 = 21.0, p < 0.0001$
Older or longer resident divers on Bonaire	$\chi^2 = 10.4 \text{ and } \chi^2 = 14.6, \text{ both } p < 0.02$
More likely to consider the reef unhealthy or very unhealthy	
Older divers	$\chi^2 = 19.0, p = 0.015$
Divers on Bonaire who a longer residents	$\chi^2 = 22.8, p = 0.029$
Divers on Curaçao with more experience	$\chi^2 = 31.7, p < 0.0001$
Divers over 45 more likely than younger divers to consider reef condition has gotten much worse	$\chi^2 = 17.4, p = 0.008$
More likely to note species absences	
Fishers with more years of fishing experience	$\chi^2 = 11.0, p = 0.012$
Older divers	$\chi^2 = 9.9, p < 0.02$
Divers with more local experience	$\chi^2 = 51.2, p < 0.02$
Divers with more total experience	$\chi^2 = 8.5, p < 0.02$
Causes of degradation (fishers versus divers; Fig. 3)	
Divers more likely to blame fish decline on overfishing, small mesh nets, spearfishing, and coastal development	$\chi^2 = 6.6, 71.5, 25.4, 7.6, \text{ and } 57.4 \text{ respectively, all } p < 0.04$
Fishers were more likely to blame change in climate, change in currents, SCUBA diving, and the will of God	$\chi^2 = 43.0, 43.0, 7.6, \text{ and } 34.0 \text{ respectively, all } p < 0.03$
Divers more likely to support gear restrictions, marine reserves, and other assorted conservation measures	$\text{all } p < 0.0001$
Fishers more likely to support no diving areas	$p < 0.001$
Divers more likely to support no fishing areas	$p < 0.001$
Baseline scores	
Fisher scores higher than diver scores	$p < 0.0001$
Older divers had lower baseline scores than younger divers	$F_{1,209} = 14.67, p = 0.0002$
Fishers on Bonaire with lower baselines scores were more likely to support gear restrictions and assorted conservation measures	$F_{1,49} = 5.9 \text{ and } F_{1,49} = 7.65 \text{ respectively, both } p < 0.02$
Support for increased management	
More divers than fishers support more fishing management	$\chi^2 = 14.0, p < 0.001$
More divers than fishers support more diving management	$\chi^2 = 6.4, p = 0.04$
More fishers and divers on Curaçao than Bonaire support more fishing management	$\chi^2 = 27.4, 15.0, \text{ both } p < 0.001$
More divers on Curaçao than Bonaire support more diving management	$\chi^2 = 27.7, p < 0.0001$

Fishers are somewhat more likely than divers (89% versus 81%) to believe there are fewer fish in the ocean now relative to ten years ago. Neither fisher nor diver responses differed between islands or across age groups or years of experience. When fishers with more than ten years of experience ($N = 167$) were asked how catch had changed in the last ten years, 83% responded that catch was worse or much worse, with no differences in response distributions between islands or age groups (Fig. 2(b)). Compared to fishers interviewed in 1995 (Debrot and Nagelkerken, 2000), a greater portion of our interviewees thought catch had gotten much worse.

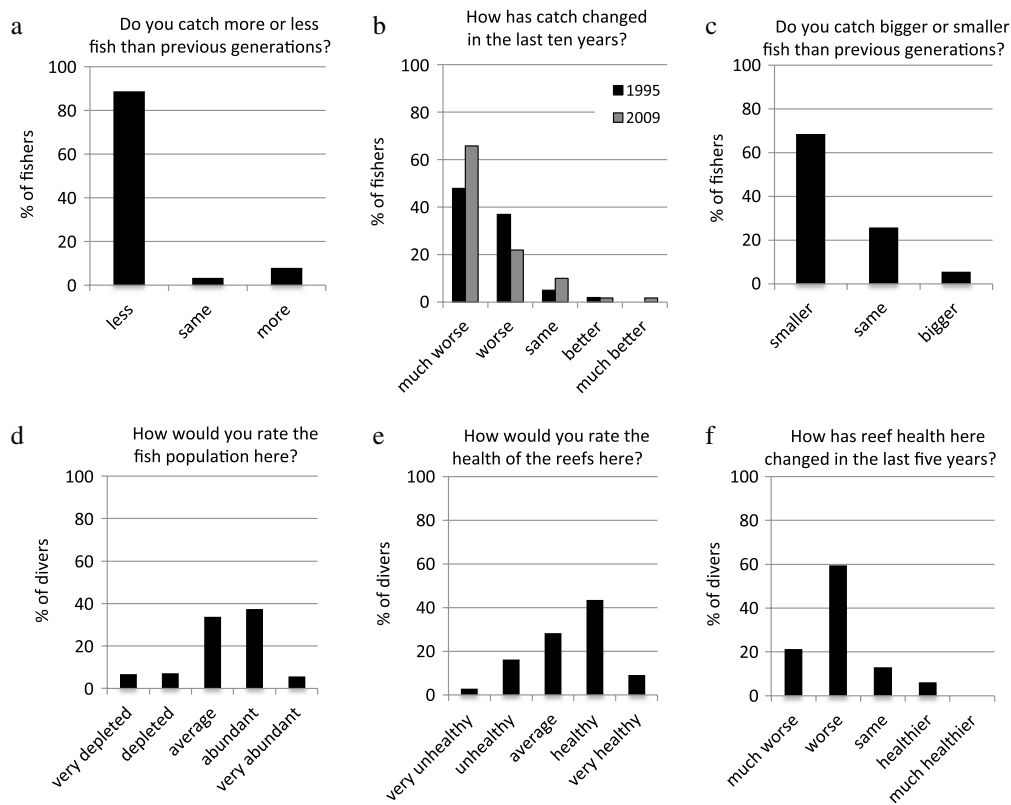


Fig. 2. Responses of fishers (a)–(c) and divers (d)–(f) on Curaçao and Bonaire to questions about fish catch and coral reef and fish population health. Question (b) was posed only to fishers with ten or more years of experience, and 1995 data are interpolated from Fig. 2 in [Debrot and Nagelkerken \(2000\)](#). Question (f) was posed only to divers with five or more years of experience.

The mean year in which fishers reported having the best catches of their lives was 1998, and the mean worst year was 2009. Overall, interviewees most frequently reported their worst year as the year the interview took place. Young and less experienced fishers were more likely to report recent years as their best.

The majority of fishers (69%) reported catching smaller fish than previous generations ([Fig. 2\(c\)](#)), with no effect of island, age group, or experience. Several fishers who reported catching bigger fish than previous generations added the caveat of having better equipment. Five fishers noted catching smaller fish despite better equipment. Comparing his catch with previous generations, a fifteen-year-old fisher remarked, “Now we show fish size horizontally [held hands shoulder-width apart] instead of vertically [held hand at shoulder height of the ground].”

There was no specific question for divers about change in the size of observed fish, yet 47% of divers commented unprompted on the absence or decline of large fish, with more divers on Bonaire than Curaçao remarking on this (58% versus 31%). More experienced divers were more likely to mention a lack of large fish, as were divers on Bonaire who were older or had more local experience. A 44-year-old diver remarked, “I miss the big fish. Some places it’s like diving in a saltwater aquarium—all these little fish.”

3.3. Reef health, site abandonment, and missing species

Most divers (81%) perceive local reefs to be average or better than average compared to how they think a healthy reef should look, with only 3% of divers considering the reefs very unhealthy ([Fig. 2\(e\)](#)). Older divers were more likely to consider the reefs unhealthy or very unhealthy, as were divers on Bonaire with more local experience, and divers on Curaçao with more overall experience.

Of divers with five or more years of local experience ($N = 114$), 81% consider reef health worse or much worse compared to five years prior ([Fig. 2\(f\)](#)). There were no significant effects of island, local experience or total experience, but on Bonaire, divers over 45 years old were twice as likely as those under 45 to consider reef health much worse (32% versus 16%).

Approximately half of interviewees (48% of fishers and 57% of divers) reported abandoning some fishing or diving locations due to reef or fish population degradation. There were no effects of island, age, or experience on fishers’ responses. Some fishers explained they have not abandoned sites because there is nowhere else to go, or their boats or engines are not large enough to go where there are still fish. There were no effects of age or total experience for divers, although (due to storm damage) divers on Bonaire were more likely than those on Curaçao to have abandoned degraded dive sites (70%

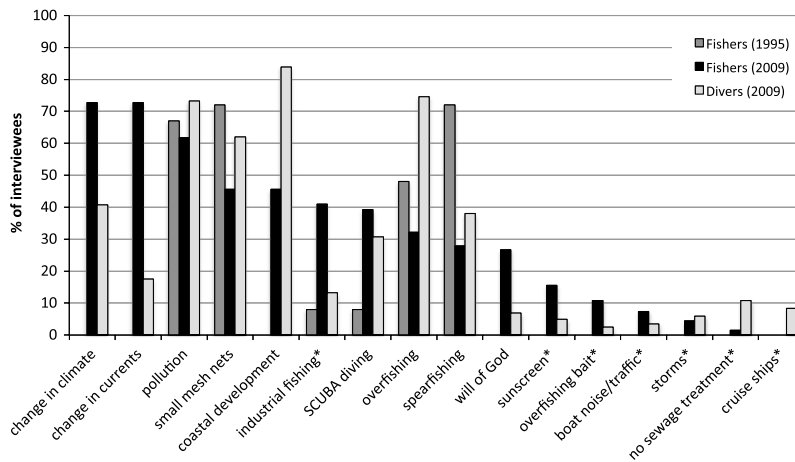


Fig. 3. Perceived causes of declines in fish populations according to the present study and data collected in 1995 (Debrot and Nagelkerken, 2000 and the associated unpublished appendix). Asterisks denote factors that interviewees were not questioned about directly, but more than 5% of fishers or divers mentioned as additional contributing factors.

Table 3

Mean scored interviewee responses to questions about reef and fisheries management, where higher numbers represent more conservation-oriented responses, and with standard deviations in parentheses.

	Gear score	Reserve score	Conservation score	Baseline score
Fishers	53.6 (22.0)	36.2 (34.4)	46.5 (18.3)	5.02 (0.1)
Divers	75.0 (22.4)	69.4 (21.6)	72.5 (15.1)	3.22 (0.1)
F-value	89.6	133.4	231.3	162.7

versus 45%). On Curaçao, likelihood of dive site abandonment increased with local diving experience. Some divers noted their employers require them to continue diving at sites they would otherwise abandon.

An overwhelming 96% of fishers and 94% of divers with over five years of local experience reported that some species they used to catch or see are rare or missing now, with no significant difference between professions. Fishers most frequently mentioned large pelagic fish (i.e., tunas, wahoo, dorado) as greatly reduced. For reef fish, fishers most commonly mentioned reductions in coney (*Epinephelus fulvus*), groupers (especially Nassau groupers (*Epinephelus striatus*)), and yellowtail snappers (*Ocyurus chrysurus*). Divers most commonly mentioned groupers (again Nassau groupers in particular), green moray eels (*Gymnothorax funebris*), lobster (*Panulirus argus*), and barracuda (*Sphyraena barracuda*).

3.4. Causes of decline and support for management

Fishers and divers differed sharply in perceived causes of fish decline (Fig. 3). Divers were more likely than fishers to blame pollution, overfishing, small mesh nets, spearfishing, and coastal development. Fishers were more likely to blame change in climate, change in currents, SCUBA diving, and the will of God. There were no effects of local or total years of experience. Industrial fishing offshore, sunscreen chemicals scaring away fish and damaging corals, and overfishing bait were the most commonly volunteered additional causes. Compared to Curaçaoan fishers in 1995 (Debrot and Nagelkerken, 2000 and associated unpublished appendix), fishers today appear less concerned with small-mesh nets, spearfishing, and overfishing, and more concerned with the impacts of industrial fishing and SCUBA diving (Fig. 3). Fishers were asked if their fishing reduces the number of fish that will be in the ocean next year or if it damages the reefs; only 11% responded yes to each question. Divers were asked whether diving damages reefs; 94% responded yes.

Divers were more likely than fishers to support gear restrictions, marine reserves, and other assorted conservation measures (Table 3). Fisher support of gear restrictions and assorted conservation measures increased with age. Among divers on Bonaire, support for reserves decreased with age. Mean baseline score was higher for fishers than divers; that is, fishers were more likely to report resource degradation. Older divers had lower baseline scores (i.e., less shifted baselines) than younger divers. Fishers on Bonaire with lower baseline scores were more likely to support gear restrictions and assorted conservation measures.

Only 2% of fishers were willing to limit the number of fishers, whereas 34% of divers were willing to limit the number of divers. Sixty-two percent of divers supported closing areas to diving, versus 37% of fishers who supported closing areas to fishing. Unsurprisingly, fishers were more likely than divers to support no diving areas and vice versa for no fishing areas.

Most broadly, the large majority of interviewees (71% of fishers, and 83% of divers) believed there should be more management of fishing, with more fishers and divers on Curaçao holding this viewpoint than their counterparts on Bonaire (79% versus 49%). The majority of interviewees (63% of fishers and 76% of divers) also believed there should be more

management of diving, with more divers on Curaçao than Bonaire (91% versus 60%) ascribed to this view, and no significant inter-island difference in fishers' responses.

4. Discussion

4.1. Fisher and diver perceptions are more similar than different

The coral reef ecosystems of Curaçao and Bonaire are in better condition than most places in the Caribbean, but have degraded substantially in recent years due to insufficient management of fishing and coastal development (Jackson et al., 2014). In general, both fishers and divers perceive this decline, although there are some important differences in their perceptions.

Fishers perceive a larger decline in fish populations than do divers. In previous surveys, Curaçaoan fishers unanimously stated that length, weight, and quantity of catches had declined, groupers and snappers were now rarely if ever caught (Schultink and Lindenbergh, 2006), and they had "all but written-off demersal and reef fishing along the southwest coast" because "a total collapse has taken place in the last decade" (Debrot and Nagelkerken, 2000). Remarkably, younger fishers have the same grim perception of fishing conditions as their older peers, and there is no evidence for a shifted baseline in relation to age as documented elsewhere (Sáenz-Arroyo et al., 2005; Ainsworth et al., 2008; Bunce et al., 2008).

In contrast, divers have a rosier view of the health of fish populations and reefs due to their comparative lack of historical perspective. This shifted baseline is reflected in younger and less experienced divers being less likely to consider the reefs degraded and declining, or to have noticed changes in fish size or species composition. The lack of independence of these variables, and the positive correlation between divers' ages and baseline scores, further buttress this result.

Demographics can explain these differing perceptions of fishers and divers, at least in part. Fishers are generally older, more experienced, and have a long family history of fishing. This has created an oral history, an inter-generational knowledge transfer. The limited timeline of SCUBA diving's existence, and the youth and high turnover of professional divers, likely explain why divers' baselines are shifted. Furthermore, while fishers' incomes are directly related to the kinds, numbers, and sizes of fish they catch, divers' incomes are less immediately coupled to reef health—the number of dive tourists and dive shops on these islands has increased even as the health of the reefs has declined, though we anticipate that trend will not last.

Differences in fisher and diver perceptions of declines in fish populations are accompanied by differences in perceived causes of these trends. Fishers tend to blame large-scale factors, while denying that their fishing has an effect. Divers tend to blame local factors, especially fishing. Thus, it is somewhat surprising that divers are not more pessimistic about the state of reefs and fish populations. Their optimism may reflect a lack of historical ecological knowledge, or a desire to maintain the reputations of these islands as premier dive destinations.

Fishers' responses were consistent between islands, whereas divers' responses differed. Divers on Bonaire were more likely than those on Curaçao to perceive current fish populations as abundant, but also more likely to perceive declines in presence of large fish and reef health. Furthermore, older and more experienced divers on Bonaire were more likely to have perceived these negative trends than newer divers. This makes sense given that, relative to Curaçao, Bonaire has maintained a larger population of large reef fish in shallow water until more recently (Wells, 1988; Sandin et al., 2008; Steneck et al., 2011). Bonaire also has only 15% of the resident population density per square kilometer as Curaçao, and one quarter the density of tourists (Jackson et al., 2014). Fishing pressure is lower on Bonaire, and there is a stronger conservation ethos. However, there was less support for additional management of fishing and diving on Bonaire, perhaps because considerably more management is already in place there. But taking a step back, the reefs and the perceptions of them are more similar than not on both islands.

4.2. Social underpinnings of the differences in opinions among fishers and divers

Understanding stakeholder perceptions of coral reefs is critical to designing socially and politically palatable management. Differences in perceptions between fishers and divers have policy implications. In an apparent contradiction, fishers are more cognizant than divers of declines but less supportive of management. Beyond the notoriously independent spirit of fishers, this may reflect their belief that they are not causing the problem, which makes restrictions on fishing feel like scapegoating. Fishers have few alternative employment options and strong cultural ties to fishing, and are therefore resistant to having fishing activities constrained, even if they can envision the long-term benefits of such measures. Divers were also reluctant to have their activities constrained, with only one-third of divers supporting limits on the number of divers, despite almost universally acknowledging that diving damages the reefs.

The financial differences between these groups are profound. Concurrently conducted behavioral economics research with the same survey participants found fishers to be less financially patient than divers because they cannot afford to wait for the long-term benefits of sustainable management and marine protected areas (Johnson and Saunders, 2014). Thus it is critical to carefully manage the transition from existing fishery management regimes to more sustainable ones to ease the burden on fishers.

Racial differences are also relevant. Divers are overwhelmingly white and foreign, while fishers are overwhelmingly black and Antillean, and the sting of colonialism is often barely below the surface. Thus, a balanced, nuanced management

approach is needed. While tourism is the main economic driver, fishing is important socioculturally and to a different demographic. Age differences are also important. Older fishers are more supportive of management than younger fishers, presumably because they have witnessed the decline of their fishery first hand. In contrast, younger divers were more supportive of reserves than were older divers, implying a potential tipping point in the professional consensus of that sector as older divers retire.

4.3. Implications for management

Despite all these differences between fishers and divers, both groups largely agree on two critically important matters: health of the reefs and fisheries is severely and increasingly threatened, and more and better management is needed to turn this situation around. Moreover, only around half of interviewees even consider their profession profitable, thus, it is unsurprising that the number of fishers on Curaçao and Bonaire has rapidly declined, and they do not want their children to be fishers. This gives the governments a mandate to more strongly manage ocean resources because both groups agree there is big problem, and their livelihoods depend on it being solved. The question is which management interventions can ensure fishers can continue to fish while dive tourism can also thrive.

In seeking solutions, we must note that both sectors cause significant damage to the environment. Fishers tend to get picked on because their impacts are so immediate and obvious, but impacts of tourism can be just as bad (Jackson et al., 2014). The damage SCUBA divers cause by kicking and touching reefs is as much of a concern as fishers depleting key fish species, especially given the explosion in the numbers of divers (Hawkins et al., 1999; Barker and Roberts, 2004). For example, an interviewed dive instructor described how conflicted he is about pointing out seahorses to tourists, because while that leads to bigger tips it also creates a halo of damage as tourists all try to get close and take photos. Research strongly supports his observations (Uyerra and Côté, 2007). This sort of diver damage is a global problem that has spawned the Greenfins movement (<http://www.greenfins.net/>) to train professional divers to minimize impacts of their clients. However, success of this and other voluntary diver education programs has been modest, and restrictions on divers need to be formally incorporated into reef management. Thus, both sectors need to be regulated, and we must recognize that there is a carrying capacity for both.

4.4. Recommendations for management

Bonaire currently has a few small marine reserves, including two closed to diving, and a suite of fishing gear restrictions. Curaçao also has gear restrictions but has not established any reserves closed to fishing or diving. Despite the dedicated efforts of several well-informed and devoted civil servants, current management is inadequate to stem declines in reef health around both islands.

Several policy actions are essential to providing the foundation for long-term sustainable use of coral reefs around Curaçao and Bonaire. First, establish large no-take marine reserves that are closed to both fishing and diving. These reserves should be established at the most ecologically valuable sites, not places no one is keen on using anyway. Marine reserves can help combat the shifting baselines problem by restoring areas and opening a window into the past (Bohnsack, 2003; Knowlton and Jackson, 2008). More broadly, ocean zoning based upon intensive community consultation can provide stakeholders with priority areas for their use, thereby minimizing conflicts and creating conservation zones (Johnson, 2014).

Second, limit the number of fishers and divers. The large proportion of elderly fishers, and overall decline in number of fishers, provide resource managers an opportunity to limit their numbers going forward, potentially with low social resistance since few young people are pursuing the profession. Following the law of supply and demand, limiting the number of divers could create a higher-value boutique tourism market.

Third, educate stakeholders about historical ecosystem baselines to ensure long-term support for strong management measures. Divers could benefit from interactions with elderly fishers who have important historical knowledge (Johannes et al., 2000). Fishers could benefit from learning more about the ecological impacts of fishing. Tourists could benefit from more deeply understanding how severely they damage reefs. And, scientists could benefit from learning how to ensure their coral reef research produces policy-relevant results. Although there is an increasing trend toward researchers including more stakeholder data, it is not enough, and many scientists neglect to make policy recommendations based on the results of their research (Johnson et al., 2013).

Fourth, ease the transition to more sustainable use of coral reef resources. Buy-outs of both fishers and divers could hasten the process. It may be appropriate to establish buyback programs for types of fishing gear or dive shops that are phased out. Heightened recreational dive fees could be used to offset short-term losses and strengthen protections. Many of the would-be next generation of fishers and divers could also be trained to help monitor and enforce protected areas.

Taking these actions in concert would increase expectations of ecosystem abundance and productivity, facilitate development of appropriately ambitious ecosystem recovery goals, and reduce the strain of the transition to sustainable management. The economic and cultural futures of fishing and diving depend on such measures, and strong, science-based management.

Acknowledgments

We thank the fishers and divers who generously shared their time and knowledge, and wonderful translators K. Brown, M. Brown, J. Vollenbregt, D. Abraham, C. Dovale, H. Liber, and M. Chirino. F Dilrosun, R. de León, E. Beukenboom provided generous logistical support and historical perspective. S. Sandin, T. Groves, L. Levin, and M. Lauer provided valuable comments. A.E.J. received funding from NSF Graduate Research, NSF IGERT Grant No. 0333444, Switzer Foundation, and AAUW fellowships, and Scripps Institution of Oceanography.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at <http://dx.doi.org/10.1016/j.gecco.2015.04.004>.

References

- Ainsworth, C.H., Pitcher, T.J., Rotinsulu, C., 2008. Evidence of fishery depletions and shifting cognitive baselines in Eastern Indonesia. *Biol. Cons.* 141, 848–859.
- Barker, N.H.L., Roberts, C.M., 2004. Scuba diver behaviour and the management of diving impacts on coral reefs. *Biol. Cons.* 120, 481–489.
- Bernard, H.R., 1994. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. Sage Publications, Thousand Oaks, CA, p. 585.
- Bohnsack, J.A., 2003. Shifting baselines, marine reserves, and Leopold's biotic ethic. *Gulf Caribbean Res.* 14, 1–7.
- Bouchon, C.P., et al., 2008. Status of coral reefs of the lesser antilles: the French West Indies, the Netherlands Antilles, Anguilla, Antigua, Grenada, Trinidad and Tobago. In: Wilkinson, C. (Ed.), *Status of Coral Reefs of the World: 2008*. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia.
- Bunce, M., Rodwell, L.D., Gibb, R., Mee, L., 2008. Shifting baselines in fishers' perceptions of island reef fishery degradation. *Ocean Coast. Manag.* 51, 285–302.
- Central Bureau of Statistics., 2010. *Statistical Yearbook of the Netherlands Antilles*. Netherlands Antilles. Willemstad, Curaçao.
- Collier, J., 1957. *Photography in anthropology: A report on two experiments*. *Am. Anthropol.* 59, 843–895.
- Debrot, A.O., Nagelkerken, I., 2000. User perceptions on coastal resource state and management options in Curacao. *Rev. Biol. Trop.* 48, 95–106.
- Dilrosun, F., 2001. *Progress Report Curaçao Fishery Monitoring Program*. Dienst Landbouw, Veeteelt & Visserij, Willemstad, p. 13.
- Godoy, N., Gelcich, S., Vasquez, J.A., Castilla, J.C., 2010. Spearfishing to depletion: evidence from temperate reef fishes in Chile. *Ecol. Appl.* 20, 1504–1511.
- Hawkins, J.P., Roberts, C.M., Van't Hof, T., De Meyer, K., Tratalos, J., Aldam, C., 1999. Effects of recreational scuba diving on Caribbean coral and fish communities. *Conserv. Biol.* 13, 888–897.
- Hughes, T.P., et al., 2003. Climate change, human impacts, and the resilience of coral reefs. *Science* 301, 929–933.
- Jackson, J.B.C., 1997. Reefs since Columbus. *Coral Reefs* 16, supplement: S23–S32.
- Jackson, J.B.C., Donovan, M.K., Cramer, K.L., Lam, V.V. (Eds.), 2014. *Status and trends of Caribbean coral reefs: 1970–2012*. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland.
- Jackson, J.B.C., E., Sala, K., Alexander (Eds.), 2011. *Shifting Baselines: The Past and the Future of Ocean Fisheries*. Island Press, USA.
- Johannes, R.E., Freeman, M.M.R., Hamilton, R.J., 2000. Ignore fishers' knowledge and miss the boat. *Fish Fish.* 1, 257–271.
- Johnson, A.E., 2014. Small Caribbean island shows bold ocean leadership: Barbuda overhauls reef and fisheries management for sustainability. *National Geographic Voices*, Washington, DC, USA. Available from: <http://voices.nationalgeographic.com/2014/08/13/barbuda-overhauls-ocean-management-for-sustainability/> (accessed April 2015).
- Johnson, A.E., Cinner, J., Hardt, M., Jacquet, J., McClanahan, T., Sanchirico, J., 2013. Trends current understanding and future research priorities for artisanal coral reef fisheries research. *Fish Fish.* 14 (3), 281–292.
- Johnson, A.E., Saunders, D.K., 2014. Time preferences and the management of coral reef fisheries. *Ecol. Econ.* 100, 130–139.
- Knowlton, N., Jackson, J.B.C., 2008. Shifting baselines, local impacts, and global change on coral reefs. *PLoS Biol.* 6, 215–220.
- Newman, M., Paredes, G., Sala, E., Jackson, J., 2006. Structure of Caribbean coral reef communities across a large gradient of fish biomass. *Ecol. Lett.* 9, 1216–1227.
- Pandolfi, J.M., et al., 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science* 301, 955–958.
- Pandolfi, J.M., et al., 2005. Are U.S. coral reefs on the slippery slope to slime? *Science* 307, 1725–1726.
- Pauly, D., 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol. Evol.* 10, 430.
- Sáenz-Arroyo, A., Roberts, C.M., Torre, J., Cariño-Olvera, M., Enríquez-Andrade, R.R., 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. *Proc. R. Soc. B* 272, 1957–1962.
- Sandin, S.T.A., Sampayo, E.M., Vermeij, M.J.A., 2008. Coral reef fish and benthic community structure of Bonaire and Curacao, Netherlands Antilles. *Caribbean J. Sci.* 44, 137–144.
- Schultink, R., Lindenberg, S., 2006. Intensiviteit van de visserij op Curaçao.
- Steneck, R.S., Arnold, S., DeBey, H., 2011. Status and trends of Bonaire's coral reefs: Cause for grave concerns. *Tourism Corporation Bonaire*, 2011. Bonaire Tourism: Annual Statistics Report 2010.
- Uyarra, M.C., Côté, I.M., 2007. The quest for cryptic creatures: Impacts of species-focused recreational diving on corals. *Biol. Cons.* 136, 77–84.
- Wells, S.M. (Ed.), 1988. *Coral Reefs of the World. Volume 1: Atlantic and Eastern Pacific*. UNEP/IUCN, IUCN, Gland, Switzerland and Cambridge, U.K./UNEP, Nairobi, Kenya.
- Zaneveld, J.S., 1961. The fishery resources and the fishery industries of the Netherlands Antilles. *Proc. Gulf Caribbean Fish. Inst.* 14, 137–171.