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ENVS 628 Environmental Problem Paper No. 2

Scuba Diver Access and Stressed-Reef Ecosystems in Florida Keys National Marine Sanctuary

The coral reef ecosystems of the Florida Keys have long attracted those seeking marine adventures in the form of boating, fishing, snorkeling, and scuba diving. After decades of heavy exploitation, with early warning signs of reef degradation by the mid-nineteenth century, Florida and the federal government began setting aside portions of the Florida Reef Tract as preserves. Florida acted first, establishing John Pennekamp Coral Reef State Park off Key Largo in 1960 (National Oceanic and Atmospheric Administration 2011). The federal government followed in 1968 with Biscayne National Monument (now Biscayne National Park) in 1968 (National Park Service 2006), Key Largo National Marine Sanctuary in 1975 and Looe Key National Marine Sanctuary, off Big Pine Key, in 1981 (National Oceanic and Atmospheric Administration 2011). The Key Largo and Looe Key sanctuaries were included within Florida Keys National Marine Sanctuary in 1990 (National Oceanic and Atmospheric Administration 2011).

The problem

Of the recreational uses mentioned above, scuba diving is a fairly recent development. For all practical purposes, recreational diving began with the development of the first modern self-contained underwater breathing apparatus (SCUBA), called the Aqua-Lung, by Jacque-Yves Cousteau and Emile Gagnon in 1942 (U.S. Navy Supervisor of Salvage and Diving 2008; PADI 2005a; Marx 1990). Books and movies by Cousteau and the husband and wife pair of Hans and Lotte Hass, along with fictional depictions of scuba diving in shows like *Sea Hunt*, which starred Lloyd Bridges, helped drive rapid growth in the popularity of the sport in the years after World War II (Marx 1990; Norton 1999; National Association of Underwater Instructors 2012). Florida—which along with California served as one of the bases for the shooting of *Sea Hunt*—soon became a mecca for would-be divers with it's large population, pre-existing reputation as a desirable tourist destination, and ready access to the sea.

The increase in popularity of scuba diving poses risks for preferred diving destinations, however. By the 1980s, researchers began to document damage to dive sites, particularly to coral reefs, caused by divers. Mechanical damage caused by boat groundings and anchoring, by divers' intentional or incidental contact with the reefs, or by lost or poorly secured gear can take a heavy toll on reef organisms, particularly hard and soft corals, over time (Barker and Roberts 2004; Chadwick-Furman 1995; Davis and Tisdell 1995; Fernández-Márquez et al. 2010; Hawkins and Roberts 1993; Luna, Pérez, and Sánchez-Lizaso 2009; Rouphael and Inglis 2002; Talge 1993; Tratalos and Austin 2001; Zakai and Chadwick-Furman 2002). The adverse effects of scuba diving may exacerbate damage to coral ecosystems from other causes, such as overfishing, disease outbreaks, coral bleaching, and ocean acidification (Allen 1992; Aronson et al. 2003; Buddemeier et al. 2003; Carilli et al. 2009; Carpenter et al. 2008).

The diving community recognizes this as a problem. It is a modification of the "Tragedy of the Commons" (Hardin 1968). The commons problem was initially described in terms of resource consumption—such as overgrazing of livestock or overharvesting of fisheries—in which an individual is tempted to abuse a common resource for short-term gain at the expense of maintaining sustainable levels of the resource for the long term. In this case the problem is not sustained yield, rather the problem is in maintaining a healthy reef environment and an optimal diving experience for future generations of divers. A diver could grab hard corals while observing fish, drag gear through underwater forests of soft corals, and leave lost gear such as lead weight behind—all without diminishing the quality of his or her experience while that damage was inflicted. Future divers (as well as reef organisms) would be the ones to suffer the consequences of such careless and callous behavior.

In order to avoid such a tragedy, certification agencies address diving impact on aquatic organisms from the start of the certification process, such as in the Professional Association of Diving Instructors (PADI) open water diver instruction manual and video (PADI 2005b, 2005c). Such impacts continue to be addressed in the agency's reference materials such as the *Encyclopedia of Recreational Diving* (PADI 2005a) and outreach activities, such as its partnership with Project AWARE (Project AWARE Foundation 2011). Even so, more experienced divers are more concerned with the effect of their diving on coral reefs and more likely to be embarrassed if they accidentally harm reef organisms (Anderson and Loomis 2011). The difference between novice and experienced divers is understandable. In part, their first experiences on a reef are often full of the "rapture of the deep," but in terms of excitement and wonder rather than nitrogen narcosis (Cousteau and Dumas 2004). Novice divers are also likely more preoccupied with basic matters like breathing underwater and finding the anchor line for an ascent when their air gets low than on how they affect reef organisms. But given the research demonstrating that both divers' skills and awareness of scuba-inflicted damage to reef organisms improve over time, education appears to have the potential to exert a significant and powerful effect on diver behavior.

Possible approaches

The easiest approach—in terms of implementation—to reduce scuba diving-induced damage to stressed reefs is to restrict diver access to those sites. Sites can be closed completely, or access can be rationed using some form of permitting system. Either solution, by reducing the number of dives on a site, would lessen the opportunity for diving-related damage to be inflicted and give stressed coral reefs some breathing space, so to speak, to deal with the other environmental stressors affecting their health. Closing sites altogether, while theoretically easy to implement, has a number of problems, however. Among these are equity, or fair distribution of resources and costs (Stone 2012). The reefs of the Florida Keys National Marine Sanctuary are a kind of commons, held in trust by the federal government for the benefit (tangible or otherwise) of the American people. Among the benefits used to justify setting aside portions of the reef tract for protection is recreation; but some of that recreational benefit would be denied for the portions that were closed to diving activity. There would be substantial economic costs, too. In the year 2000, divers spent an estimated $25 million in Monroe County, Fla., generating more than $3 million in wages and supporting nearly 250 full- and part-time jobs (Johns et al. 2003). While the economic impact of scuba diving was less than that of snorkeling or fishing, loss of that income could have a drastic effect on the Keys' economy. Aside from equity issues, closing off portions of the reef might an unforeseen, and possibly more damaging, effect—by denying scuba-diving citizens the opportunity to see reef damage as it happens, it might undermine public awareness of and support for tackling environmental problems such as climate change that seem remote in terms of time and space.

Restricting access through some kind of lottery/permitting system would not be as drastic as reef closures. The only feasible way to administer such a system would be to issue permits to boat owners and operators. A totally random lottery system would hardly be equitable, however. Permits alone would determine economic survival of the dive shops, not safety, or quality of boats, equipment, or personnel. Dive shops with a strong safety and customer satisfaction record, but without permits, would have a hard time staying in business. Dive shops with a habit of losing customers (in the deep or onshore), but with permits, would have an easier time than they deserve remaining in operation. Diving consumers forced by a permitting system to choose substandard dive operations would be deprived of the safe and enjoyable dive experiences they deserve. If individual boat owners were allowed to participate on an equal footing with commercial dive operations for permits, the boat-owning individuals—who would most likely be wealthier than the average person—would tie up diving opportunities in affected areas of the Florida Keys to the detriment of the vast majority of the scuba diving community, in particular the non-resident scuba diver. That in turn would have a disproportionate effect on the local economy in that the non-resident diver spends considerable amounts of money on lodging, food, and transportation (Johns et al. 2003).

A third approach would be to deploy the scuba equivalent of game wardens, officers with the power to cite, and possibly detain in egregious cases, dive operators and divers who damage reef ecosystems. This solution is not particularly practicable: while federal, state, and local governments do have the ability to levy fines in the case of boat groundings or hazardous material and fuel spills—as in the case of the R/V Columbis Iselin grounding on Looe Key Reef in 1995 (Sanctuaries Web Group 2006; National Oceanic and Atmospheric Administration 1997)—fielding a sufficient number of dive officers to adequately police individual diver behavior would likely be cost prohibitive in terms of wages, training and equipment costs, and liability and workman's compensation insurance. An inadequate officer presence would likely have no significant effect in reducing reef damage, and any officer presence would likely add to the stress that novice divers, which would be the ones most likely to damage reef organisms through poor diving practice, are already feeling about a dive, putting them at greater risk of having an accident that endangers their health—even their life—and possibly spoil their dive experience. In the long term, it would likely harm the local economy by driving potential dive visitors away to reef areas with little or no police presence.

Prohibition-, permit-, and enforcement-based approaches are examples of hierarchical, command-and-control policy tools (Richards 2000). The state (as in government in general) either prohibits or rations access to the resource. A permitting system could be operated on an incentive basis (Richards 2000) basis—i.e., auctioning of permits—but many of the objections to such a system, at least from a individual diver's viewpoint, remain. With respect to the problem of reducing diving-related damage, such a system could reduce the number of divers on stressed sites, but ultimately would do nothing to improve diver behavior while there. The enforcement-based approach above would encourage, or more accurately, coerce, better diver behavior, but if implemented at a level that might produce measurable benefits would have significant adverse effects in terms of implementation cost, diver and officer safety, dive experience and economic sustainability.

The proposal

Given the problems with restricting diver access to reefs, it seems a different policy solution should be pursued. Therefore, the recommendation herein is to establish a voluntary certification program for dive operators to encourage better diving behavior and technique while on vulnerable reefs. Lest this sound like a wishful and impotent call for good behavior, the elements of this solution are eminently practical.

The first step begins with diver education. Among the skills aspiring divers are taught is buoyancy control. Unless a diver is ascending or descending, he should be neutrally buoyant so that he rises slightly when he inhales and sinks slightly when he exhales. A properly trained and practiced diver can hover at an essentially constant depth for long periods just by controlling breathing. By proper buoyancy control, divers avoid contact with obstacles such as coral reefs or jagged edges on wrecks. They avoid stirring up sediment that obscures visibility—an inconvenience on a reef, but potentially lifesaving in wreck or cave environments. Buoyancy control is a difficult skill to master, but hang lines, commonly used for safety stops on the way back to the surface from a dive, can be used as a visual reference on the way down for divers to practice buoyancy before dropping the rest of the way onto the reef.

Another skill is maintaining proper trim. When a diver swims, unless he is changing depth or swimming around an obstruction, he should be horizontal in the water. This is achieved by the proper distribution of weight around the diver's body. Modern buoyancy control devices (BCDs) are worn like vests, while weights are work on a belt or in special pockets in the BCD. Either way, weights are concentrated around the waist. A poorly trimmed diver's head and shoulders are pulled upward, while the weights pull his waist and hips downward. Aside from making the diver work harder to get through the water, poor trim—with arms and legs often flailing as the diver struggles to maintain a proper attitude—will make incidental contact with reef organisms more likely.

The next problem is partly an education issue, and partly a technological issue. Poorly secured equipment is another important source of diver-caused reef damage. Alternate air sources, depth and pressure gauges, and underwater cameras are examples of three types of gear divers take with them into the water which will drift, drag, and damage anything they come into contact with if not secured to the diver's BCD. Scuba students are taught how to properly secure such gear using clips, keepers, and other devices. But sometimes the clips or keepers used to keep this gear in place does not work very well. For example, the high-pressure hoses between the regulator first stage (the part of the regulator that attach to the scuba tank) and the instrument console containing the submersible pressure gauge (SPG) and other instruments often slides within its keeper. While the keeper makes it easier for the diver to find, the console still can easily drag along the bottom if the diver is not careful. Likewise, the traditional alternate second stage (which another diver low on air may breathe off of) may slip out or be kicked out of its keeper and drag, too. Changes in equipment reduces the odds of this type of damage, however. Spring-loaded retractors can be used in place of traditional clip-style console keepers. BCDs that combine the low-pressure inflator (used to control the amount of air in the BCD) with the alternate second stage eliminate the need for a long hose and keeper that pose a dragging risk.

Scuba divers are supposed to be a self-sufficient lot—buddy system notwithstanding—so for some dive operations it is not unusual that divemasters remain aboard the boat while divers are left to themselves underwater with the expectation that they will dive safely and responsibly. While there is much in diving culture and reality to recommend such expectations, it is also true that mistakes, and deadly ones for either divers or marine life, occur. Part of this might be remedied by having some divemasters present in the water to watch for and solve diver problems before they escalate into something more than a nuisance. Whether the hovering divemaster acts more like Sergeant Barnes or Sergeant Elias in the Oliver Stone movie *Platoon* makes little difference as long as he or she can quickly get to a diver in trouble—or about to cause trouble—and help him get in control of their buoyancy or gear before someone or something gets hurt.[1] Where reason or communication fails, the divemaster could redirect a recalcitrant diver to a portion of the reef where he can do little or no damage until time to return to the surface.

Another role for the divemaster to help minimize diving impacts is in the pre-dive briefing. During a briefing, divemasters typically describe the physical setting of the dive site—depth, visibility, entry and exit points, interesting features—as well as tips for safe diving, such as suggested bottom times for the depth/gas mix combination, decompression procedures (if relevant), and hazards. During these briefings the divemaster can also stress ways to avoid, or at least reduce, diver impacts on reefs. Buoyancy control, equipment issues, suggested dive techniques, etc., can be addressed here. Furthermore, the divemaster can use this opportunity to educate divers about what is happening to stressed reefs. Describe the signs of damage or stress; what causes it, whether it be disease, pollution, overgrazing or something else; and where on the reef it can be found. Whatever the divemaster accomplishes, he should at least avoid the "shifting baseline syndrome" (Pauly 1995) by driving home the message that the reef is not OK, that the current state is diminished from what it was when it was healthy.

The final element of the plan is to require dive shops to ensure that diver-supplied or rental gear meets minimum standards in order to reduce reef damage. This begins with the BCD. Weight-integrated BCDs eliminate the need for separate weight belts. Weight belts are known to slip off, and as they fall they can hit other divers or the reef below. The weight-integrated BCDs

[1] In my career as a divemaster, I employ elements of both.

should be designed, as many now are, to ensure that weight pouches do not easily fall out.[2] Regulator and octopus design should likewise been streamlined. Traditional regulator assemblies have four hoses coming out of the first stage: one to the primary second stage, one to the alternate second stage, one that attaches to the low-pressure inflator on the BCD, and one that runs to a console containing the SPG and other instruments—which may include a dive computer, depth gauge, and compass. The hose to the secondary second stage can be eliminated by using a BCD design which combines the alternate air source with the BCD's low-pressure inflator. The SPG console can be secured using a spring-loaded retractor rather than the traditional clip-style keeper. (A further hose could be eliminated by using a radio transmitter attached to the regulator first stage and a receiver built into a wrist- mounted dive computer, but as this technology is expensive and difficult for novice divers to master, this latter solution probably should not be required.) Cameras and dive lights should be attached to coil connectors with snaps to keep the gear close to the body when not in use.

Scientific Justification

Policy solutions involve some application of power. A popular definition of power in social science circles was developed by Max Weber (1925) in his posthumously published book, *Wirtschaft und Gesellschaft*. The original German definition has been variously translated into English, but a workable translation for the current purpose is, "Within a social relationship, power means every chance (no matter whereon this chance is based) to carry through the own will (even against resistance)," (Wallimann, Tatsis, and Zito 1977). John Kenneth Galbraith (1983; Galbraith and Bartel 1983) subsequently classified power into three types: 1) condign power, in which one's will is imposed through force or coercion; 2) compensatory power, in

[2] Unless it is necessary to drop weights in an emergency, as scuba divers are trained to do.

which the fulfillment of one's will is essentially purchased through some form of inducement; and 3) conditional power, in which others are persuaded to follow one's will because it is the right and proper thing to do.

The challenge is in determining what type of power is most effectively applied to the problem of diving-related damage to reef ecosystems. Prohibition- and enforcement-based approaches are examples of condign power; permit-based approaches can represent either condign or compensatory power, depending on how they are administered. The recommended solution, however, is an application of conditional power, and it is likely the most effective way to induce long-term changes in diver and dive operator behavior that will have equally long-term benefits on reef ecosystems.

The reasons why conditional power is more likely to succeed has something to do with the nature of the commons problem. Some have likened it to an environmental version of the prisoner's dilemma (Dawes 1975; Dawes, McTavish, and Shaklee 1977; Luce and Raiffa 1957; Buckley, Burns, and Meeker 1974) in which a member of a group can make a rational decision in his best interest (in this case, to exploit the environment) that is detrimental to the group's long-term common interests. The dilemma is that while one group member may reap greater benefit by acting selfishly rather than cooperatively, if too many members of the group act in like manner, the payoff per person may be less than if all group members cooperated.

Stern (1976) pointed out some problems with the equation of the commons problem with the prisoner's dilemma: 1) individuals can act in ways that shield them from the effect of the actions of others; 2) the prisoner's dilemma does not allow for intragroup controls, such as shaming, that can have a significant coercive effect on individual behavior; 3) the prisoner's dilemma applies to situations where group members interact directly and does not allow interactions outside the group; and 4) the prisoner's dilemma does not extrapolate well to a commons involving depletion or destruction of a finite resource—all members of the group will eventually feel the effect of its depletion or destruction. Rubinstein et al. (1975) suggested that the combination of scarcity and incentives can increase the conservation of a dwindling resource. Kelly and Grzelak (1972) found that an individual's increased awareness of the long-term consequences of decisions affected a group corresponds with a greater willingness to act in a cooperative manner. The two results inspired Stern (1976) to argue that policy tools that involves both incentives and education—which may combine all three types of power, but which always includes significant emphasis on conditional power—can lead to greater conservation and prolong the life of a common resource such as a coral reef ecosystem.

In this case, the incentives are offered to the dive operator to participate in the program. The reward is something the operator can use in branding his business as ecologically friendly and in turn be rewarded with the patronage of green-minded divers. While the dive operations also benefit from the education aspect, the main beneficiaries are the divers themselves, who, it is hoped will improve their diving skills and modify their behavior in a way that ensures the long-term health of the environment they presumably love to recreate in.

Others have found value in incentives and education as a policy tool in the decades since Stern described the concept. Santopietro (1995) suggested that incentives and education approaches are more cost effective than more coercive methods, and Forsyth et al. (2002) found that education-added programs were more effective than programs based on incentives alone. Incentives and education are now incorporated into conservation programs around the world (Richards 2000; Salafsky et al. 2001; Kaine et al. 2006; Kingsford et al. 2009). Using the education component to shifting the time horizon with which the target population views their world is important, as having long-term viewpoints increase the likelihood of meaningful behavioral change (Rabinovich, Morton, and Postmes 2010).

Equities

This solution, by allowing access to the dive site, would to a large extent eliminate the equity problem associated with site closure—that of access to a resource held in common for the benefit of all the citizens of the United States. It would preserve access, yet that access would by necessity be unequal because scuba diving has a long history of merit-based equity distribution. The scuba diving industry learned long ago that people should not dive without a certain minimal amount of training. This is because the sport of diving comes with certain inherent dangers: risk of death due to running out of air, rapid ascents causing decompression sickness or pulmonary embolism, entanglement or entrapment, or other medical causes for which evaluation and treatment cannot be rendered until the patient is brought to the surface; barotropic injuries to ears and sinuses from changing depth without equalizing, and other injuries from contact with obstacles or marine life. Most scuba certification agencies, such as the National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI), or the British Sub-Aqua Club (BSAC) have a hierarchical system of certification in which divers earn greater privileges (such as the ability to dive to greater depths) as they successfully complete additional training. To some extent, "privileges" is the wrong word in that divers can do what they want once they are in the water, but the limitations are clearly explained during the certification process.

For example, under the PADI system[3], newly minted open-water divers can dive to 60 feet. With an advanced open-water certification, they can dive to 100 feet, and with a deep diver certification, they can dive to the recreational limit of 130 feet, the deepest one can dive without having to undergo decompression. Beyond that, divers require technical diving certification which trains them in an array of decompression procedures and the use of alternative gas mixes. Also, open water divers are limited to an air mix. Before one can rent or fill tanks with a nitrox (elevated oxygen) mixture, they must obtain a nitrox certification. Other certifications, such as wreck, night, and cave diving, earn divers the ability to dive in the respective specialized environments. The price of adhering to this merit-based system is the loss of freedom to go and do as one will once in the water—sometimes even getting in the water, as most dive shops around the world will not allow divers to rent or fill scuba tanks, or get alternate gas mixes, unless the diver provides evidence of qualification in terms of certification cards and log books.

The preferred solution may add rank-based equity concerns. In this case, rank is determined by budget. This again is nothing new in the scuba-diving world, as personal funds determine the quality and amount of gear a diver can afford, the number and types of certifications that can be obtained, and the type and distance of dive sites they can access. The low-budget diver who ordinarily could afford a trip to South Florida may be priced out of the trip by higher rental fees if his personal equipment does not meet the minimum standards required under the policy solution.

Aside from individuals, equity issues may affect the dive operations as well. Dive operations forced to upgrade their rental gear may be at a competitive disadvantage to shops in other regions not required to maintain such standards, though the effect would likely be minimal, for gear that

[3] In full disclosure, all of my certifications are through PADI, including my divemaster certification (No. 240478).

is properly maintained can last quite a few years, and most dive shops have staff qualified to handle the appropriate maintenance—a recurring cost regardless of how old a shop's gear is.

Diffuse support goals

One of the main diffuse support goals that would be bolstered by this policy is environmental awareness. People who never or seldom travel to the ocean rarely give any thought to how our actions affect distant seas. While many recreational divers today do experience the sea, whatever they see on a coral reef is often much more interesting than what they can see in the quarry or lake they routinely dive in back home. They have no frame of reference to compare what they see on a reef now to what they could have seen 50 years or 100 years ago before overfishing, pollution, and climate change began sapping the resilience of reef communities. Pre-dive briefings, coupled with guidance from divemasters underwater, can help them develop more empathy for reef organisms, more willingness to make the personal changes necessary to stave off environmental disaster, and more inspiration to share with their family, friends, and neighbors the need to do more to conserve our precious and dwindling ocean resources.

Another diffuse support goal promoted by this policy is an improved dive experience in terms of safety and enjoyability. Safety is promoted in a number of ways, by the pre-dive briefing, by the improved quality of equipment divers will be used, and by the supervision—to the extent possible—of the divemasters while in the water. Every dive briefing should address safety issues anyway, but an emphasis on controlled buoyancy, ascents, and descents may help divers avoid many types of barotrauma, such as ear damage. Emphasis on buoyancy as well as trim may help divers avoid getting cramps or getting tired, both of which may necessitate a rescue by a divemaster or fellow diver. Better gear, such as weight-integrated BCDs, tends to be both safer and simpler for an inexperienced diver to use. Standardized gear helps divemasters help divers both in setting up for a dive as well as assisting divers in distress. An experienced and observant divemaster in the water can identify, intervene in, and halt a potential crisis before it erupts beneath the surface.

Adverse effects

Any adverse effects would be primarily economic. Mandating an investment in updated gear would pose a mostly one-time cost to affected dive operations. A more significant cost to affected dive operations would be that of having additional divemasters in the water. Aside from wages and benefits, costs related to additional divemasters include liability insurance and training. Aside from acquiring and maintaining dive-related skills, divemasters who routinely go to sea may require additional Coast Guard-mandated safety and boat-handling courses. Of course, affected dive shops would also have to train employees according to guidelines mandated by the program to ensure that reef-friendly knowledge is properly imparted to their diving (and snorkeling) clients—but the ability to receive and benefit from that knowledge adds value to their customers' diving experience.

Public involvement

The policy recommendation herein requires public involvement—involvement on the part of the dive operator as well as the diver. Of the types of solutions that might be implemented, it is the only one that substantially depends on the public for implementation and maintenance. It has an advantage of dovetailing with mainstream scuba educational and ethical standards with respect to minimizing, if not halting altogether, damage to the reef environment. Given the potentially lifelong reinforcement from the major diving certification organizations and non-profits such as Project AWARE and Reef Check (Reef Check Worldwide 2007), it seems likely that such a program, despite some increased costs to dive operations and dive consumers, will engender the "...common sense of purpose to many people…" (Kempton, Darley, and Stern 1992) that is needed to inspire the public to pull together and address the myriad environmental issues that sap the health and vitality of the world's oceans.

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