PROCEEDINGS

JOINT INTERNATIONAL SCIENTIFIC DIVING SYMPOSIUM

AMERICAN ACADEMY OF UNDERWATER SCIENCES

and

EUROPEAN SCIENTIFIC DIVING PANEL

Michael A. Lang and **Martin D.J. Sayer**

Curaçao, October 24-27, 2013

The American Academy of Underwater Sciences (AAUS) was formed in 1977 and incorporated in the State of California in 1983 as a 501c6 non-profit corporation. Visit: www.aaus.org.

The AAUS Foundation was incorporated in the State of Alabama in 2012 as a 501.c.3 not-for-profit organization.

The mission of AAUS is to facilitate the development of safe and productive scientific divers through education, research, advocacy, and the advancement of standards for scientific diving practices, certifications, and operations.

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FOREWORD

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The American Academy of Underwater Sciences (AAUS) and European Scientific Diving Panel (ESDP) Joint International Scientific Diving Symposium in Curaçao, October 24-27 2013, marks the third time that the AAUS has held its annual meeting in partnership with other international scientific diving organisations. Jointly sponsored AAUS symposia occurred in 1985 with CMAS (Confédération Mondiale des Activités Subaquatiques; Mitchell, 1985) and in 1998 with the Canadian Association for Underwater Science (CAUS; Hartwick et al., 1998).

The AAUS and the ESDP share commonalities in their mission and objectives. They both represent a considerable number of scientific divers performing diving-based research covering the full range of scientific disciplines. Underwater scientific research is often conducted on an international scale in regions that frequently face growing pressures on resources and increased threats of pollution, urbanization of habitats, invasion by alien species, extreme weather events and sea-level change. The relatively shallow and multifaceted nature of many coastal areas can restrict the types of platforms that can be deployed in support of relevant research. Scientific diving is a cost-effective high-quality research tool that can sustain a wide range of scientific disciplines within operationally expedient timeframes. It has particular use in complex environments such as subtidal rocky substrates or urbanized habitats (marinas, wrecks, offshore wind farms, etc.) that are routinely inaccessible for study by other methods. Scientific diving has also provided unique multidisciplinary datasets that add value to other ocean observation platforms (Lang et al., 2013).

This symposium convenes scientists of multiple nationalities in an attempt to reduce insularity, encourage exchange of ideas and operational protocols, and expand the worldwide network of scientific divers. This joint initiative provides a forum that will highlight some of the research findings from within the international research communities. We are experiencing a developmental period of large-scale multi-national research programs established to observe, record and monitor change over various geographical scales. Engendering a research framework for scientific divers that facilitates multi-national collaboration is of immediate and long-term benefit.

Irrespective of the symposium venue selected, the diving scientist increasingly experiences cutbacks in research funding, extreme pressure in travel budgets and intense competition for proposal-dependent funding, not to mention government shutdowns. The island of Curaçao was identified for this symposium because of its historical ties to Europe, its proximity to the Americas and as a desirable venue for workshops such as coral reef ecology, performance freediving and a post-symposium field trip to Bonaire. The presence of Substation Curaçao's CURASUB provides delegates the opportunity for deep-reef observation dives and CARMABI and CIEE are local research organizations in Curaçao and Bonaire providing perspective on long-term coral reef research in the Caribbean. We are hopeful that the connections created through this joint international symposium will advance scientific diving as a research platform on a global scale.

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THE ROLE OF VOLUNTEER DIVERS IN LIONFISH RESEARCH AND CONTROL IN THE CARIBBEAN

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The Indo-Pacific lionfish (Pterois volitans) is a venomous, voracious predator that is currently causing ecological and economical harm throughout the Caribbean. Their generalist diet and habitat preference coupled with their rapid growth rate and lack of natural predators has allowed their population to explode throughout the Caribbean. As a means to control lionfish populations, countries have designed lionfish removal programs which, in some instances, depend primarily on volunteer divers. Activities such as lionfish tournaments or specified lionfish removal trips and events are another platform whereby volunteer divers help to remove substantial quantities of lionfish. These removal events are important for lionfish control, and they contribute greatly to research. In Bonaire, since October 2009, almost 5,000 lionfish have been submitted to CIEE Research Station Bonaire by volunteer divers for research on lionfish morphometrics, sexual maturity and feeding ecology. This submission of specimens has contributed to one of the most in-depth and long-term studies of lionfish feeding ecology in the Caribbean. Staff from CIEE have also attended lionfish hunting tournaments in Curaçao to collect data on lionfish ecology and make comparisons. During the first tournament in 2012, 317 fish of the 1,069 caught were analysed, whereas in 2013, 1,500 fish out of 2,403 caught were dissected. Thus, within two days an extensive sample size was attained from various depths throughout various locations in Curaçao, an achievement that would have taken a small group of researchers many weeks or even months. Thus, volunteer divers have the ability to play an instrumental role in lionfish research and control and should be implemented into further lionfish management strategies throughout the Caribbean.

Introduction

Lionfish signify the first marine fish invader from the Western Pacific to the Atlantic and are believed to have been introduced via intentional and/or unintentional aquaria releases (Morris, 2009). They are usually benthically associated and in their native range they occur over coral, sand and hard-bottom substrates from the surface to 50 m (Whitfield et al., 2002; 2007; Vasquez-Yeomans et al., 2011). In their invaded range, they have occupied all major seafloor and substrate types and occupy a range of depths, from the shoreline to more than 300 m deep. During the day, lionfish linger under ledges and crevices, but may hunt small fish, shrimps and crabs in the open water at night (Ruiz-Carus et al., 2006). Lionfish are adaptable to many habitats and have colonised areas ranging from 1 to 140 m on reef walls, patch reefs, rocky areas, hard bottoms, ledges, crevices, mangrove creeks, isolated coral heads, blue holes, ship wrecks, and man-made structures (NOAA's Coris, 2009). Lionfish tend to live in small groups as juveniles and during reproduction but disperse and hide in reef shadows when they are adults (Fishelson, 1997).

Based on captured specimens in the Caribbean, lionfish are reproducing throughout the year (REEF, 2012). Their reproduction shows no apparent timing relative to moon and tidal regimes, and a continuous supply of propagules is generated (Department of Marine Resources, 2008; Morris, 2009). Lionfish are prolific breeders with one female being able to eject up to 15,000 eggs during a single mating event, of which she can have at least three per month (Bervoets, 2009). The eggs are bound in an adhesive mucus that disintegrates a few days later, allowing the embryo and/or larvae to become free-floating (Hare and Whitfield, 2003; Morris et al., 2009). As they are not thermally limited in their native range, they can continuously reproduce throughout the year. The actual larval distribution of lionfish still remains unknown but has been estimated to be between 25-40 days (Morris, 2009). Laidig and Sakuma (1998) reported a larval growth rate of 0.33 mm day^{-1} for *Scorpaena*, a genus in the Scorpionfish family. Applying this estimate to the estimated 25-40 day larval duration, it can be suggested that larvae are in the water column and consequently susceptible to transport by ocean currents for approximately one month (Hare and Whitfield, 2003). Settling from the water column to the benthic habitat is proposed to occur at a total length of about 12 mm (Hare and Whitfield, 2003). The juveniles develop rapidly and begin to actively hunt at approximately 7 cm total length and have been observed to consume prey up to two-thirds their body length (Bervoets, 2009).

Lionfish are principally piscivorous but are known to feed on invertebrates (Morris, 2009). In their native range they occupy the higher levels of the food chain (Hare and Whitfield, 2003; Bervoets, 2009). In the Bahamas, the occurrence of teleosts in lionfish diets is size-dependent with larger lionfish feeding on teleosts and smaller lionfish feeding more heavily on crustaceans (Morris, 2009; Morris and Akins, 2009). Bervoets (2009) suggested that lionfish consume 10% of their body weight every day, whilst Morris (2009) proposed that lionfish have the ability to consume 2.5 to 6.0% of their body weight per day at 25-26^{o}C. Lionfish stomachs can expand to more than 30 times in volume (Freshwater et al., 2009). Lionfish are adept in undergoing periods of starvation of over 12 weeks without mortality because of their capability of long-term fasting (Fishelson, 1997; Morris, 2009). They can employ a diverse range of feeding strategies making them well suited for feeding on benthic and cryptic prey. Prey species in the Atlantic region are naïve to lionfish's novel predation strategies, resulting in lionfish having higher predation efficiencies in the invaded range compared with its native range.

Since their invasion of the North Atlantic/Caribbean region, various management measures have been instilled to quell lionfish populations (Morris et al., 2010). Lionfish management has been an evolutionary process in terms of the schemes established, the tools used, and the means to increase removal efforts (De Leon et al., 2011). At the beginning of the lionfish invasion, scientists and government or state department officials were the primary persons involved in lionfish removal. However, because of the invasion characteristics of lionfish, there is need for a larger, community effort to enhance the chances of more successful removal (Morris et al., 2012). Removal activities were introduced to dive operators and professionals and further extended to volunteer divers, no matter what their dive certification level (BNMP, 2010); this has been instrumental in the successful control and management of lionfish in some islands in the Caribbean.

Case Studies

Bonaire

Bonaire is a prime example of how the use of volunteer dives can be a successful means to control lionfish populations. The control, management and monitoring of lionfish in Bonaire is achieved through an intricate partnership between STINAPA (nature enforcement agency on the island), CIEE Research Station Bonaire, dive operators and volunteer divers. Not only do volunteer divers remove considerable quantities of lionfish, but they also submit a large proportion of their catch so that research can be conducted. Since the first lionfish sighting on 26 October 2009, more than 5,000 lionfish have been submitted to CIEE Research Station Bonaire. This represents one of the largest and most long-term lionfish datasets in the Caribbean; this would not have been possible without the commitment of volunteers. Time and especially monetary restrictions mean that scientists themselves are unable to achieve such a large sample size. However, for research purposes, large sample sizes are desired especially for dietary studies because a large proportion of the stomach content already tends to be too digested for analysis (Cocheret de la Moriniere et al., 2003). A larger sample size is also able to reveal the full spectrum of prey items in lionfish diets and any temporal changes (Hyslop, 1980; Pierce et al., 2004). Research has focused on lionfish ecology, primarily their feeding preferences, their growth rates, their reproductive status and their habitat and depth preferences. Conducting research on lionfish and monitoring any changes in their growth rate, diet, habitat and depth preferences helps to predict and quantify how lionfish may impact on the ecosystem, especially when coupled with prey density surveys (Morris et al., 2012).

Conducting research also acts as an important education and training tool. In Bonaire, all findings are communicated to the public via lectures, newsletters and postings on social media. There is also high involvement with the local schools with educational workshops whereby students get educated on the lionfish invasion and are then given the opportunity to view live lionfish and conduct research through an interactive dissection workshop. Getting the locals, especially the youth, involved is imperative as they can act as ambassadors and educate others. In Bonaire there is also a fantastic partnership between CIEE and the STINAPA Junior Rangers. This program targets the young people of Bonaire in the 12-21 age group. All Junior Rangers have received a lionfish education whilst those over the age of 18 have received training on lionfish removal. These Junior Rangers diligently attend lionfish removal trips offered by CIEE and GOOODIVE and have improved tremendously; they are now the top hunters on these trips. These Junior Rangers act as ambassadors to other youngsters who are aspiring to learn more about lionfish and become lionfish hunters themselves.

Klein Bonaire

Bonaire is renowned as being a shore diving heaven, which makes lionfish removal in Bonaire so convenient. However, Klein Bonaire is only accessible via boat, which accounts for a lower hunting pressure. As a result, a research and removal program was initiated in early 2012 whereby the entire island of Klein Bonaire would be covered. On each trip, a group of 8-10 hunters would remove lionfish from a particular dive site but also keep track of data such as the depth of capture, how many lionfish were missed, lionfish aggregation and behavior. Following the dives all lionfish were measured, weighed, dissected and their reproductive status and stomach contents analysed. Following analysis, lionfish were either sold to restaurants or used personally by hunters.

Figure 1 reveals a reduction in the number of lionfish seen at Klein Bonaire, from 2,240 in 2012 to 854 in 2013. The lionfish hunters in Bonaire have become more efficient at removing lionfish. Improving from a 40% successful capture rate in 2012 to 63.5% in 2013 is especially commendable because lionfish themselves have become ‘smarter’ and have learnt to associate divers with danger, thus making removal activities more difficult.

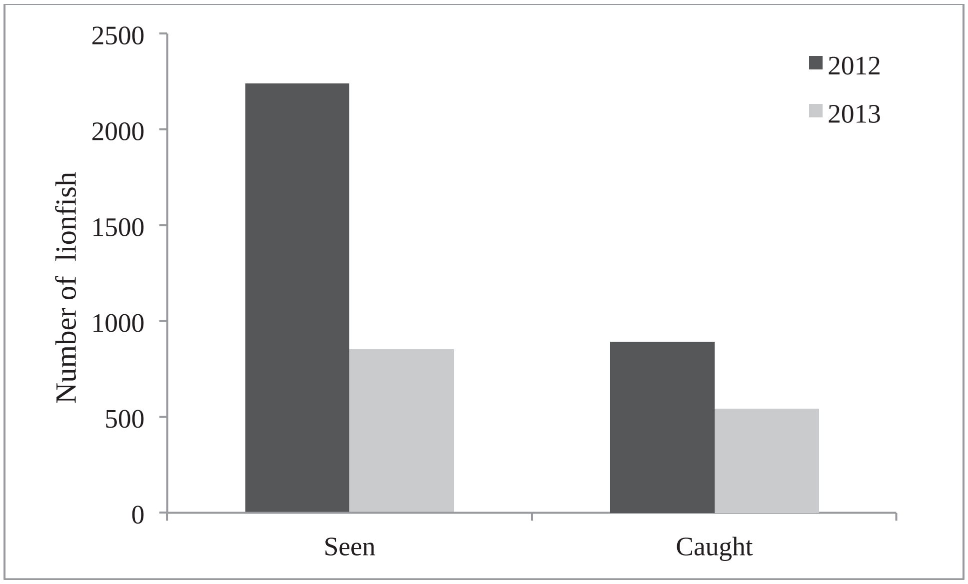

Figure 1. Comparison of the number of lionfish seen and caught at Klein Bonaire in 2012 and 2013

Curaçao

Lionfish were first confirmed in Curaçao on 27 October 2009 (NACRI, 2009). Since 2012, three lionfish tournaments have been hosted in Curaçao (Table 1). Personnel from CIEE Research Station Bonaire were present at the 1st and 3rd tournament, whilst scientists from CARMABI were on-hand to conduct research during the 2nd tournament. During the 1st tournament, 317 lionfish were analysed whereas during the 3rd tournament, an impressive 1,497 lionfish were analysed by CIEE staff.

Table 1. Diver participation and number of lionfish caught during tournaments in Curacao.

Tournament	No. Scuba divers	No. Freedivers	No. Lionfish Caught
1) March 2012	20	4	1084
2) August 2012	11	0	1591
3) April 2013	44	0	2403

Lionfish collected during the tournaments in Curaçao were used for an analytic comparison with fish collected at Klein Bonaire and Bonaire. Despite the close proximity of these islands to one another, there were some interesting differences with respect to lionfish feeding preferences, differences that may not have been discovered with a smaller sample size. Similarities of the top prey species in lionfish's diet were also observed amongst the three islands, which helped to confirm and also understand how lionfish feed which could provide a basis for predicting what their future impacts may be.

Importance and benefits of volunteer divers and lionfish tournaments

Lionfish tournaments allow for large numbers of lionfish to be eradicated in quite a short space of time. The fish caught from these activities provide valuable research specimens for scientists to examine lionfish growth characteristics and their feeding and reproductive ecology, among other aspects. The large quantities of fish caught can also be used as a means to encourage the locals and the general public to eat lionfish whilst also acting as an important vehicle for public education and raising awareness (Morris et al., 2012).

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