ISSN: 1995 – 1132

CRFM Technical & Advisory Document Series

Number 2013 / 15

MANUAL FOR CONDUCTING UNDERWATER VISUAL QUEEN CONCH SURVEYS

CRFM Secretariat
Belize 2013

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MANUAL FOR CONDUCTING UNDERWATER VISUAL QUEEN CONCH SURVEYS

Prepared by:

SOFRECO, under contract to the ACP Fish II Project, on behalf of the Caribbean Regional Fisheries Mechanism (CRFM) Secretariat

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Correct Citation:
CRFM 2013. Manual for Conducting Underwater Visual Queen Conch Surveys. CRFM Technical & Advisory Document, *No. 2013 / 15*. 138p.

ISSN: 1995-1132
ISBN: 978-976-8165-97-8

Published by the Caribbean Regional Fisheries Mechanism Secretariat
Belize and St. Vincent and the Grenadines

This document has been produced with financial assistance of the ACP Fish II Programme - Funded by the European Union. However, the views expressed herein can in no way be taken to reflect the official opinions of the EU.

FOREWORD

In 2013, the EU-sponsored ACP Fish II Programme commissioned a study titled 'Training in underwater visual survey methods for evaluating the status of *Strombus gigas* queen conch stocks'. The study was executed by SOFRECO on behalf of the CRFM Secretariat, and upon completion, a Final Technical Report was submitted to the ACP Fish II Programme that contained 4 major outputs of direct interest to the CRFM: a review of underwater fisheries independent approaches to queen conch population estimation; a manual for conducting underwater visual surveys for queen conch; report of a mock survey of a sea area in the southern Grenadines of St. Vincent; and country-specific queen conch survey plans.

To make the 4 major outputs more readily identifiable as CRFM-approved, and also more easily available to the various CRFM publics, they have been extracted from the original Final Technical Report submitted to the ACP Fish II Programme, and reproduced as CRFM Technical and Advisory Documents 2013/14 (regional review), 2013/15 (manual) and 2013/16 (mock survey report and country-specific queen conch survey plans).

The CRFM Secretariat acknowledges the contribution of the EU-sponsored ACP Fish II Programme in this endeavour.

LIST OF ACRONYMS

ACP	African, Caribbean and Pacific states
ANOVA	Analysis of Variance
AUV	Autonomous Underwater Vehicles
CITES	Convention on the International Trade in Endangered Species of Wild Fauna and Flora
CLIC	Collection of Landmarks for Identifications and Characterization
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GPS	Global Position System
IRD	Institut de Recherche pour le Development
ISE	International Submarine Engineering Ltd.
LED	Light Emitting Diode
LT	Lip Thickness
MPA	Marine Protected Area
OSGeo	Open Source Geospatial Foundation
QGIS	Quantum Geographic Information System
ROV	Remote Operated Vehicle
SL	Siphonal Length
TAC	Total Allowable Catch (TAC)
U.S.	United States
WAAS	Wise Area Augmentation System
WECAFC	Western Central Atlantic Fishery Commission

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ANNEXES

QUEEN CONCH SURVEY MANUAL

CHAPTER I: INTRODUCTION

For centuries, the queen conch (*Strombus gigas*) has been one of the most iconic marine invertebrates across the Caribbean. The conch meat, shell, and pearls are all valued as important sources of income and the shell, in particular, has been widely used for construction and curios. The translucent pearls and shell are widely valued in jewellery. The shell has also been recognized as a cultural icon utilized for announcing important community events. Consequently, conch products in the Caribbean are consumed and utilized locally and are also frequently exported.

The queen conch is a tropical shallow-water species that lives in sand, seagrass, and coral reef habitats. It is subject to constant fishing pressure primarily from divers. The resource has been subjected to high levels of exploitation and, with increasing demands and prices in the international markets, the abundance of conch populations has diminished to the point that, in 1992, the species was listed in Appendix II of CITES (Convention on the International Trade in Endangered Species of Wild Fauna and Flora). This international agreement, legally binding to the Parties, is aimed at ensuring the species survival. To achieve this objective, CITES priorities include developing measures that ensure the sustainability of the fishery and counteract illegal trade. Because the early CITES measures did not stem the decline in regional abundance, two Significant Trade Reviews of queen conch were conducted in 1995 and 2003. These reviews resulted in prohibitions of queen conch exports from some countries, and further resulted in the adoption of special measures for improving non-detrimental findings.

The assessments of conch populations across the Caribbean has been difficult due to the intensity of the fisheries, biological characteristics that make the use of fishery population models difficult, and the paucity of data related to historical catch and fishing effort. As a consequence, management alternatives need to ensure harvest limitations while recognizing the importance of this traditional fishery. At present, reference points based on conch population densities have been regionally accepted as a sound practice for the maintenance of successful reproduction and recruitment.

Queen conch populations throughout the region are connected within a spatially complex patchy environment rich in coral reefs habitats comprising a variety of depths. In this context, estimations of densities of conch populations need to include spatial and temporal considerations. Underwater visual census methods provide the type of data necessary to evaluate the status of local populations, independent from the sparse and low-quality fishery-based information. These fisheries-independent approaches can provide data that will assist managers in assessing population trends that are necessary to evaluate, and to recommend management approaches that apply the precautionary approach.

Underwater visual conch survey techniques also provide important biological / ecological information at the ecosystem level while at the same time facilitating the participation of managers, scientists and users in the analysis and reporting. This approach may have direct impacts on the decision-making process by perhaps enabling greater collaboration resulting in greater trust and buy-in that support queen conch conservation policies and regulations. Nevertheless, fishery-dependent data still needs to be collected and incorporated in analyses as complementary information, in order to have a much better understanding of the complexity of the resource and to better develop appropriate fishery regulations.

The objective of this manual is to present to the broader Caribbean audience a guide to the steps needed to conduct an underwater queen conch visual survey, including the planning and design tools and methods. Data collection and analyses are covered. The biological rationale for each step is further discussed. It is expected that this manual will serve as an educational and outreach document for those people that love and appreciate the survival of the queen conch. Its use will provide an opportunity for more international cooperation, for better linkages between fishery managers and conservationists, and for better communication and exchange of information.

Because underwater surveys often require the use of SCUBA, safety considerations need to be incorporated into all surveys to minimize risks of hyperbaric trauma and, in the context of Caribbean society, the negative socio-economic impacts some queen conch communities are already experiencing.

It should be understood that the approaches and steps defined in this manual are meant to be adapted when appropriate to surveys in specific locations. In most cases, an attempt was made to broaden the applicability when describing approaches within this manual; however, in some instances some methods may seem best-suited for specific locations under specific conditions. This manual should serve as a guide for survey designers and that teams need to adapt this manual both prior to survey design, and also during the survey activities, to their particular situation.

This is a product generated by SOFRECO during the implementation of the project entitled "Training in Underwater Survey Methods for Evaluating the Status of the *Strombus gigas*, queen conch stocks" identified as the project CAR/3.2/B.14. The project is funded by the program ACP Fish II "Strengthening Fisheries Management in ACP countries" and directly benefits the Caribbean Regional Fisheries Mechanism (CRFM) and, in particular, the countries of Antigua and Barbuda, The Bahamas, Belize, Dominican Republic, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines, within the Caribbean Forum.

CHAPTER II: BIOLOGY AND ECOLOGY KEY ISSUES

Objective:

At the conclusion of this chapter, trainees will refresh / learn relevant biological and ecological aspects of Caribbean queen conch, needed for better understanding of wild populations and for developing future fishery management recommendations.

2.1. Taxonomy

Strombus gigas is a large marine gastropod, first described by Linnaeus in 1758. The species common names varies throughout the Caribbean: lambie in several eastern Caribbean countries including the French speaking ones; queen or pink conch in several Caribbean English speaking countries, lambi in Dominican Republic; caracol pala in Colombia; caracol rosa in Honduras and Nicaragua; caracol reina in Mexico; botuto and guarura in Venezuela; carrucho in Puerto Rico; cambombia in Panamá; cambute in Costa Rica; and cobo in Cuba. Recent studies in the species taxonomy may re-group some of the genus in the future. The current taxonomy is:

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
Order: Mesogastropoda
Superfamily: Stromboidea
Family: Strombidae
Genus: *Strombus*
Species: *gigas*

FAO Species Identification Sheets separate this species from others in its family due to the large and moderately heavy shell, the outer large and thick lip with a U-shaped notch, the numerous short, sharp spires, the brown and horny operculum, and the bright pink shell with yellow borders (Figure 1).

The species has been reported in Florida, Bermuda, The Bahamas, the Turks and Caicos Islands, the Caribbean Islands, the Gulf of Mexico (including Texas), as well as the Caribbean shelves of the Central and South America (Figure 2).

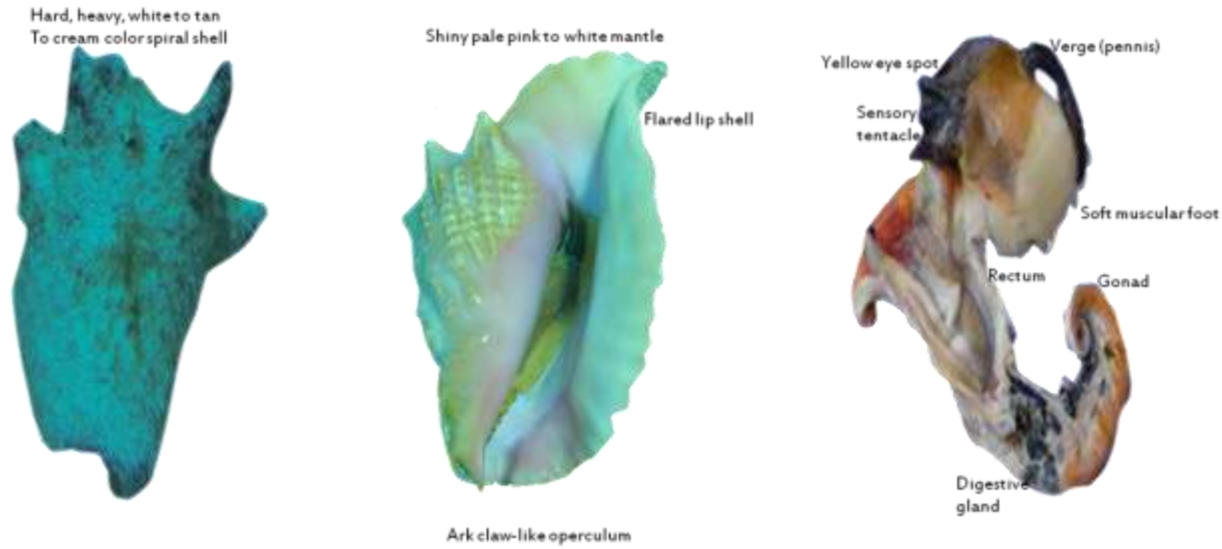

Figure 1: Pictures illustrating the queen conch morphology. Pictures taken by Martha Prada and Megan Davis.

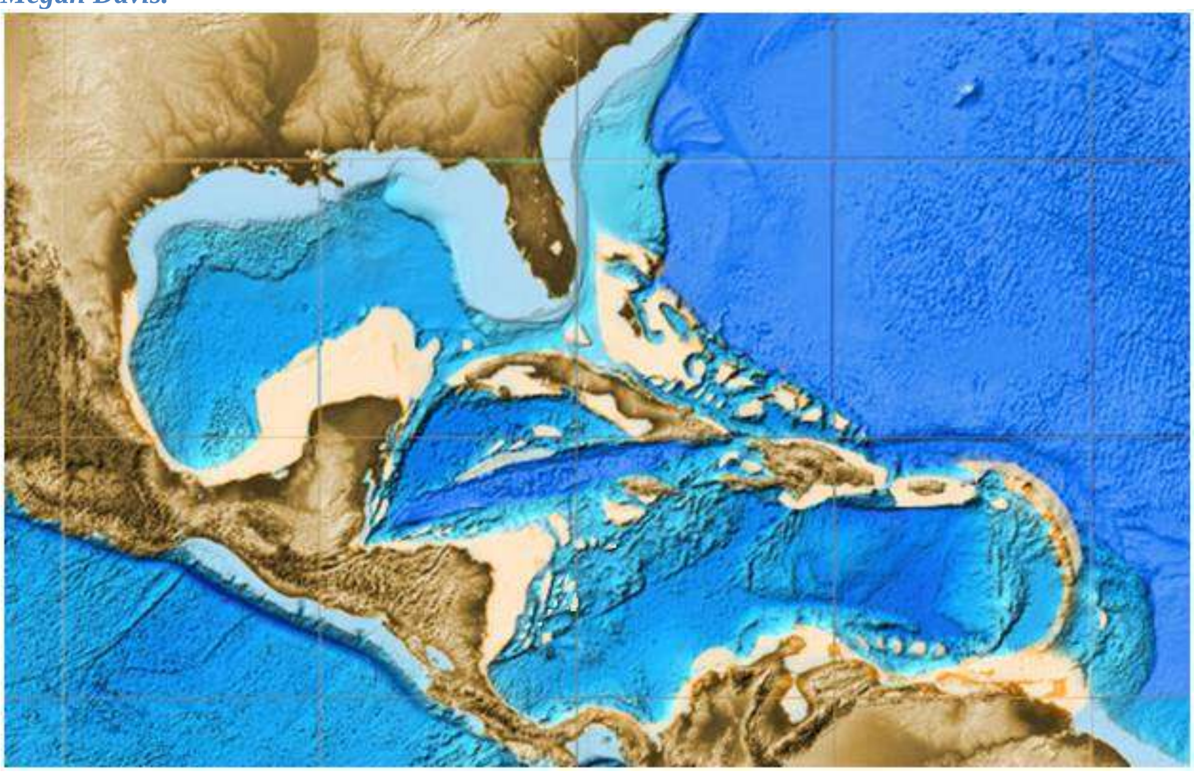

Figure 2: Highlighted (orange) shelf areas in the greater Caribbean denote the geographical distribution of the Strombus gigas or queen conch.

Based on map from NOAA National Geophysical Data Center (http://maps.ngdc.noaa.gov/viewers/bathymetry/).

2.2. Life History

As is true of many marine invertebrates, the queen conch has two life stages: one planktonic stage comprised of microscopic, free-swimming larvae, followed by a benthic stage associated with the seafloor (Figure 3). The planktonic cycle begins with the hatching of larvae from a crescent-shaped egg mass laid by adult females. Each egg mass contains from 400,000-750,000 eggs (Mianmanus 1988, Davis 1998, Aldana 2006). Egg masses are camouflaged with sand grains to aid survival through the three to four day incubation period. It is estimated, that a reproductive female can lay 7-13 egg masses per season.

The conch larvae or veliger emerges 3 - 5 days after spawning, and progressively develops multiple lobes known as the vela (singular: velum), and a transparent shell with one and a half whorls (Stoner *et al* 1992, Davis 1998). The vela assist in maintaining the buoyancy of the veligers and also serve as a mechanism to exchange gases and to direct microalgae, the main food at this stage, towards its mouth. During the first two weeks, veligers can be found at the surface and, as they age, they spend more time near the sea floor. Approximately 18-24 days after hatching, the larvae undergo metamorphosis in response to chemical cues exuded from red algae (Mianmanus 1988, Davis *et al*. 1990). Metamorphosis is achieved when the pigmentation of operculum changes from orange to dark green, the shell is larger and no longer transparent, the bronchial and muscle tissues develop, and, ultimately, the velum disappears. From now on, the queen conch will never swim again.

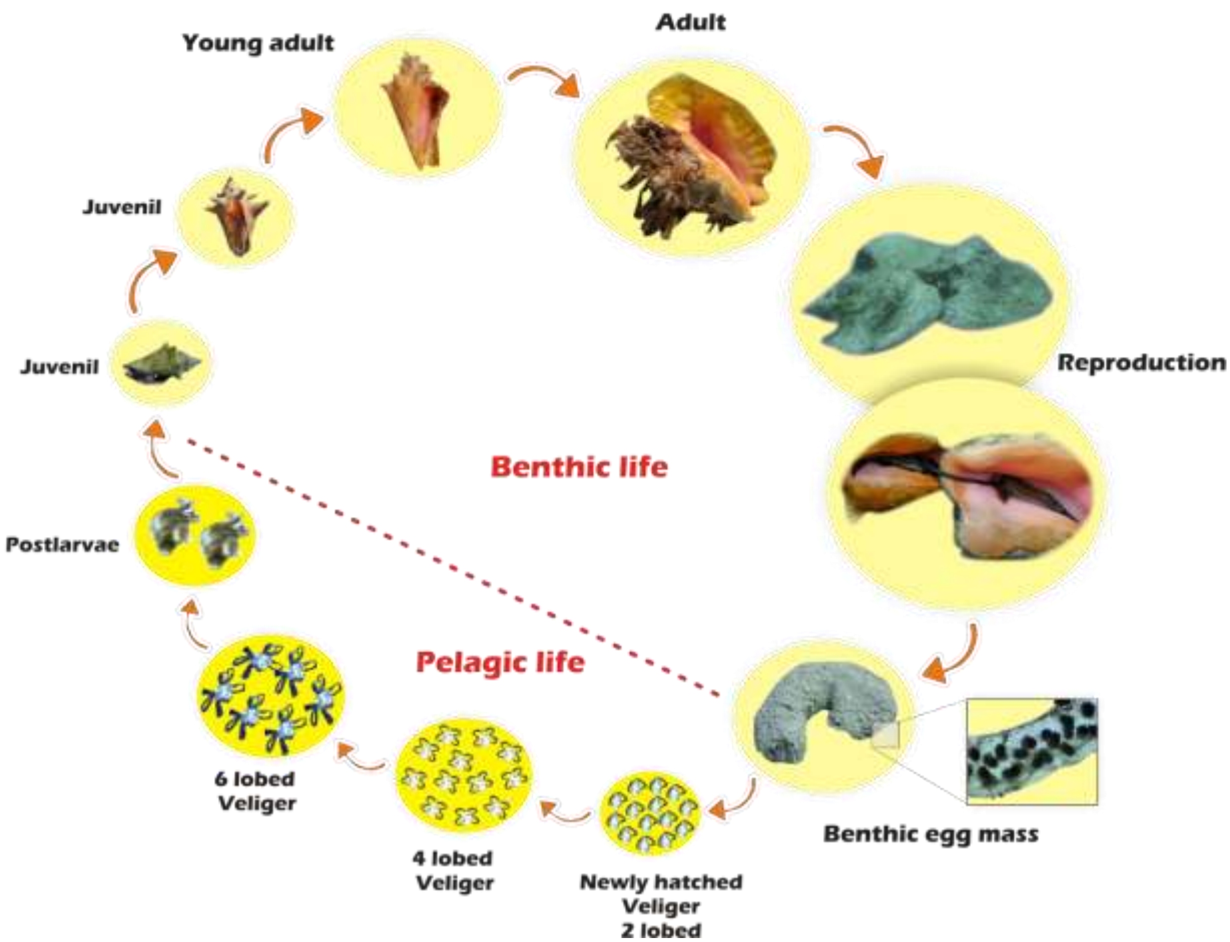

Figure 3: Diagram illustrating the several life stages of the queen conch. Pictures taken from Martha Prada, Erick Castro, Heins Bent and Megan Davis.

Early juveniles are 3 - 4mm Siphonal Length (SL). They are found buried in sandy habitats (Randall 1964, Sandt and Stoner 1992), emerging at night to feed. Progressively, the shell grows as its body grows bigger, becoming hard and thick. When the conch becomes an adult (i.e. at sexual maturation), it is about three and a half to four years old (Egan 1985, Appeldoorn *et al* 1987, Appeldoorn 1988, Stoner & Sandt 1992, de Jesus 2003). At this age, the shell is approximately 22cm SL with a lip thickness of about 5 mm. Recent studies have found that sexual maturity in queen conch does not occur until shell lip thickness reaches 8 to 15 mm (Egan 1985, Aldana-Aranda & Frenkiel 2005, Avila-Poveda & Baqueiro-Cárdenas 2006). Adult conchs have a flared lip and, as they age, the spines become blunt and worn, and the shells often become covered with algae. Smaller animals often settle on the shells as if they were rocks. It is believed that conch can live up to around 20 years; in Bermuda, a live conch was found to have a coral growing on its shell that was 40 years old.

Queen conchs have separate sexes (Figure 4) and fertilization is achieved by copulation. Spawning typically occurs from March to October (Davis *et al*. 1984, Davis *et al.* 1994, Stoner *et al.* 1996a) although in the southern part of the range, they have been observed reproducing year round. Deep water conch (more than 40 m) in the French West Indies (Guadeloupe and Martinique) matures and spawns from June to October (Frenkiel *et al*. 2009, Reynal & Aldana 2009). During the reproductive season, large numbers of conch will migrate towards shallow waters (10m or less) and breed in coarse sandy habitats near reefs and *Thalassic testudinum* seagrass beds (Robertson 1959, Randall 1964, D'Asaro 1965, Brownell 1977, Weil and Laughlin 1984, Stoner and Schwarte 1994), forming reproductive aggregations. The high densities, and the relatively shallow-water in which they are found, make them vulnerable to exploitation. Successful reproduction depends on sufficiently high densities. According to Ávila (2004), in Colombian reefs, the complete gametogenic maturation cycle occurs from April through September; spawning occurs in two seasons in March-April and September, respectively. However, there is variation across the region with regard to the size and lip-thickness that can be related directly to the gametogenesis.

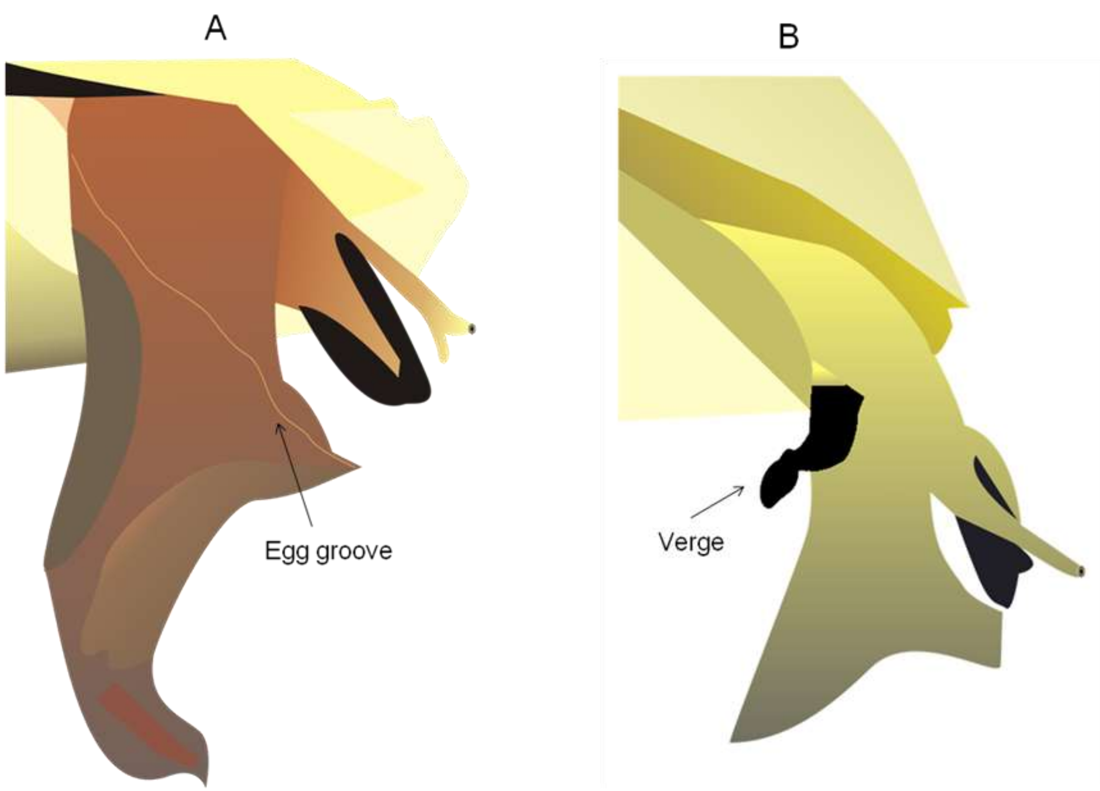

Figure 4: Illustration of queen conch sexual dimorphism: A. Female, B. Male. Drawing by Diana Prada.

2.3. Morphology

The queen conch has a large-lipped pink shell, (approximately 25cm or 10 inches SL), and has the highest commercial fisheries value of the six species within the Family Strombidae found in the western Atlantic. The head has two pairs of tentacles; the larger tentacles support the eyes whereas the smaller pair provides a sense of smell and touch. The large, muscular foot is that portion of the conch that is consumed. The foot protrudes from the lip of the shell and ends in an operculum or a hard thin oval disk that is used for locomotion, to fight with predators, and to seal itself tightly within its shell. Adult conch exhibit sexual dimorphism, with adult females having an egg groove on the right side of the foot; adult males develop a large black penis or verge also located on the right side of the foot.

The white conch meat constitutes the primary product of the fishery. However, the large, beautiful shell has also been prized by tourists (Figure 5). Queen conch pearls are less common, and by far the most valuable among the conch products. These pearls are formed by laying down concentric layers of fibrous crystals, then producing calcareous concretions with a porcelain finish. They are found in a wide variety and combination of colours including white, red, pink, orange, yellow and brown. Queen conch pearls are considered gemstones.

The measurements of the shell dimensions, the thickness of the lip, and the length of the operculum are all important morphometric variables. They are used to recognize the phenotypic variation among populations, and, in some cases, the potential differentiation of fishing stocks.

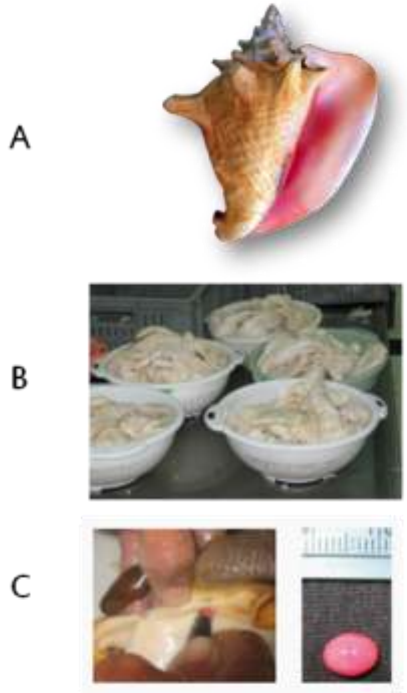

Figure 5: The three most valuable queen conch products: A. the pink shell, B. the white meat, and C. the colourful pearls. Pictures taken by Martha Prada and Oscar Ortegón.

2.4. Queen Conch Growth Variations

Variations in queen conch growth can be attributed either to genetic (heritable traits) or phenotypic (physiologic response to local conditions) factors. Currently, there is no consensus regarding the proportion that each factor influences queen conch growth at the population level. On one hand, patchy larval settlement may lead to distinct genetic populations, with perhaps periods of 5-10 years between settlement events. Alternatively, environmental conditions in different areas are associated with growth and morphological variations. Both mechanisms have the potential to influence conch growth rates and maximum size. In heavily fished sites, large conchs disappear rapidly in response to fishing and this process eventually will lead to the dominance of small individuals thereby influencing the overall growth patterns of the population. It is well established that juvenile shell growth increases exponentially, with rates decreasing as adulthood nears. The length of the shell actually stops growing at sexual maturity, when additional shell deposition is dedicated to increasing lip thickness (Berg 1976, de Jesús-Navarrete 1997). Because of this determinate growth, queen conch shell length (siphonal length) should only be used to estimate age until sexual maturity is attained; thereafter, lip thickness can serve as a proxy for age. This growth pattern makes applying fishery models to populations extremely difficult.

On the other hand, spatial and temporal variations in the queen conch growth have been well-documented for more than 50 years (Table 1).

Table 1: Spatial variation in growth rates of juvenile queen conchs.

Site	Juvenile growth rate (mm/month)	Reference
Los Roques, Venezuela	15	Weil y Laughlin 1984
Banco Chinchorro, Mexico	10	de-Jesus-Navarrete 2003
Providence Island, Colombia	10.9	Shawl *et al* 2008
Belize	7.2	Gibson *et al* 1983
Florida, US	4.5	Brownell 1977
US Virgin Islands	4.16	Randall 1964
Cuba	3.3	Alcolado 1976
Banco Chinchorro, Mexico	3.2-1.5	de-Jesus-Navarrete 1997
The Bahamas	1.74	Ray & Stoner 1994

The shell length and the thickness of the lip are usually the two most common features used to visually discriminate between juvenile and adult conchs during surveys. Unfortunately due to the variability in growth rates, not all large conchs are sexually mature, nor are all conchs with a flared lip. Therefore the relationship between length and weight is not so simple.

Additional examples of the queen conch growth variations are:

- Samba conch: a small variety of conch with a pinkish interior and a blue exterior. These conchs look old due to their thick shell. These conchs may be relatively abundant in some locations (e.g. Colombia) because fishers prefer larger conch and sometimes the conch meat is darker, and therefore less preferable, than regular conch. Small-sized stocks may result from the shallow depth, generally softer substratum, and potentially lower food concentrations in sand areas or at high density (Alcolado 1976, Martin-Mora *et al* 1995).

- Stone conch: a large variety of conch that looks very old, have eroded spines and shell covered with sessile invertebrates. These conchs are usually found in deep waters and considered to be excellent for reproduction. It is believed that the meat from these individuals is tougher compared to other conchs.

For these reasons, when establishing the relationship between length and weight it is important to consider the following issues:

- To have a representative sample size from different areas under study.

- To have a representation of all ages including juveniles, pre-adults, adults and very old adults if they are present in the population.

2.5. Mobility and Connectivity

The queen conch is characterized by its slow movements and relatively small annual home range of 0.5 - 59.6ha, Glazer *et al*, 2002). It appears that they can move faster with higher water temperatures; measurements conducted in Florida indicated that mean speed in the summer (4m / day) was approximately twice that observed in the winter and spring (approximately 2m / day) respectively (Glazer *et al.* 2002). Acoustic tagging conducted recently in Providence Island, Colombia, indicated that juvenile conch moved within an area of 0.5 - 0.6km over a period of 4 months (Erick Castro, personal communication).

In a more comprehensive study using acoustic tagging, juvenile and adult queen conch were tracked over three years in Fish Bay, St. John, US Virgin Islands (Doerr and Hill. in press). They found, that 54% of tagged adults migrated out of the bay from their primary bay habitat of patchy macroalgae over a distance of 1.7km, whereas 95% of the juveniles remained inside the bay, moving an average of 4.6m per day and occupied primarily shallow habitats dominated by seagrass.

Conchs in the Bahamas migrated from the food rich rubble community to sand habitats for reproduction (Sandt & Stoner 1992). Adult conch moved from a seagrass dominated community to a sand-algal community associated with the onset of winter in Turks and Caicos (Hesse 1979). Exhaustive surveys conducted in Quitasueño, Serrana and Roncador banks, within the San Andres archipelago, Colombia, identified the back-reef, the adjacent lagoon, and the deeper leeward pre-reef terrace as juvenile nursery habitats. Spawning areas were observed both on the northern and southern tips of the archipelago's atolls, including the "*Acropora*" reefs in Roncador´s lagoonal environment. Older adults were found in coral and sand-patch habitat as well as the deeper leeward reefs. The effects of major cuts through the forereef are believed to favour larval retention and deposition (Appeldoorn *et al* 2003).

Population connectivity is a product of mesoscale processes and ocean-island interactions. Conch larvae are capable of travelling long distances given their 3-week planktonic phase and their somewhat passive behaviour primarily in the neuston. Lonin *et al.* (2010) modelled queen conch larval advection in strong hydrodynamic environments (85 - 90 cm/s) within the San Andres archipelago and estimated larval speed at 168 m/day based on horizontal turbulence. They estimated that conch larvae have the potential to move more than 800km in less than 30 days with implications for conch populations further south and north. They also identified three patterns of connectivity that separated the southern, middle, and northern atolls. Differences among these atolls were confirmed using microsatellite genetic markers (Marquez *et al*, in press). Genetically isolated populations were identified using allozymes in Bermuda; Alacranes Reef, Mexico; Gros Islet and Vieux Fort, St. Lucia; and the Turks and Caicos (Mitton *et al*. 1989, Campton *et al*. 1992, Tello-Cetina *et al*. 2005). Delgado *et al* (2008) concluded that the Florida conch population was largely isolated based on drifter studies, plankton surveys and mesoscale circulation patterns. The ability for populations to remain isolated is an important consideration in managing a conch fishery because populations that are isolated will take longer to recover from an overfished status. These populations require conservative harvest rules when determining quotas with respect to populations that are more 'open'. Despite the increasing evidence of the isolation of some populations, the entire Caribbean region likely has some genetic exchange (Morales 2004).

Complex and dynamic oceanic circulation patterns facilitate the movement of the benthic life stages and are indispensable for the movement of the pelagic life stages. The patterns that connect juvenile and adult queen conch populations are known as demographic connectivity, and are regulated to a great extent by habitat. To understand connectivity at this scale, it is important to collect mapping information about habitat quality and distribution. This information provides a comprehensive understanding of critical landscape features that facilitate or impede movements and migrations including identification of patches and corridors (Glazer and Kidney, 2004).

At larger spatial scales, gene flow is controlled by larval dispersal and functions to define patterns of smaller populations within a larger metapopulation. Metapopulations are broadly characterized by source populations (for example, spawning populations that supply downstream populations) and sink populations (those populations that receive the larval influx); how these populations persist will affect the long-term stability and viability of the smaller populations that comprise the metapopualtion. Genetic connectivity generally measures the degree to which gene flow affects evolutionary processes within populations. Given the patchy nature of optimal conch habitat, as populations decline the ability of source populations to provide sufficient larval supplies to downstream populations becomes more jeopardized thus impacting stability at broad scales.

2.6. Fishery Considerations

The fishery of queen conch in the wider Caribbean has been in existence since pre-Colombian times, and the intensity of this fishery exploitation has increased. Queen conchs are an easy target because: a) they prefer sandy and shallow reef areas; b) they have slow rates of movement; c) they aggregate to reproduce; and d) they have a high market value for a variety of products (Prada *et al* 2009). Fishermen collect the conchs in bags primarily by diving (free-diving, SCUBA, or hookah). To a lesser extent, poles with hooks, and trammel nets are also used. The meat is often extracted at sea; however, sometimes fishermen collect the shell for the curio market. Pearls are also collected if present. Commercial conch fishing is often conducted in association with commercial lobster fishing.

To determine and regulate the sustainability of the queen conch fishery, scientists rely on stock assessment models, based on fishery-dependent data. These models analyze the relationships between population abundance indices and extraction, natural mortality and recruitment functions. Unfortunately the application of these models for the queen conch fishery has proved difficult due to the following model assumptions:

- The population represent a single stock, meaning all individuals are identical (age, growth, maturation) for all ages and sizes,
- The response of populations to changes in exploitation are instantaneous,
- The stock is in equilibrium,
- Historical data on catch and fishing effort is available,
- Available data represent the totality of the catch and fishing effort,

A simplified approach to overcome these limitations is the use of fishery-independent data obtained from underwater visual censuses. Using this methodology, it is possible to determine the density and abundance of the population by examining spatial (habitat) and temporal (seasonal) variables and then applying harvest control rules. Inferences about the sustainability of the fishery would be better understood if estimates of population abundance can be established. In this regard, visual censusing provides a robust estimate for population abundance estimation, and, therefore, strategies for sustainability can be better crafted.

Being able to identify the queen conch population abundance at the ecosystem level provides information about the potential for serial depletion, a phenomenon often attributed to conch fisheries. Serial depletion describes the progressive depletion of the fishing grounds and is often dependent on the distance from the port and the commercial importance of the species. In this model, the closest fishing grounds would be depleted first, while more distant ones would be affected later. Allocation of the fishing effort based on spatially-explicit density estimations is expected to counteract the vulnerability conch to serial depletion.

CHAPTER III: TECHNIQUES FOR UNDERWATER QUEEN CONCH SURVEYS

Objective:

At the conclusion of this chapter, trainees will improve their skills in organization, development and analysis of underwater visual census data to study queen conch stocks and to estimate sustainable levels of harvest.

3.1. Preferred Habitats

Queen conch is categorized as a specialist, being primarily herbivorous (algal / detritus feeder). As adults in large numbers they can have a major influence on benthic productivity (Stoner 1989 a, b). Young individuals, on the other hand, are micro-herbivores that feed mainly of epiphytes growing on seagrass *Thalassia testudinum*, blades. They also feed on grass detritus, macroalgae and diatoms characteristic of sandy environments (Robertson 1961, Randall 1964, Alcolado 1976, Stoner & Waite 1991, Stoner *et al*. 1995).

In The Bahamas, juveniles often occur in aggregations covering 1 to 100 ha occupying habitats with specific physical and biological conditions such as in back reef areas or in the broad reef lagoons (reviewed by Stoner 2003, Appeldoorn *et al* 2003). With age, large juveniles and adults disperse over a wide range of habitats including seagrass meadows, algae-covered hard ground, bare sand, or rodolith beds in depths to ~35 m (Randall 1964, Stoner 2003, Gómez *et al*. 2005). Adult aggregations of 150 - 200 queen conchs have been observed within an area of approximately 30 x 100 m in open sandy habitats in the San Andres archipelago. Mating and pairing behaviour were common within the aggregation (Appeldoorn *et al* 2003). In Florida, spawning aggregations may encompass areas in excess of 8 hectares (800 m x 100 m) (Glazer, unpublished).

Queen conch have a strong role in influencing shallow marine trophic structure and, therefore, tropical marine biodiversity in the Caribbean. Some of the more important predators include the tulip snail (*Fasciolaria tulipa*), apple murex (*Murex pomon*), octopus (*Octupus vulgaris*), spiny lobster (*Panulirus argus*), old wife (*Balistes vetula*), spotted eagle ray (*Aerobatus narinari),* tiger shark (*Galeocerdo cuvieri*, nurse shark (*Ginglymostoma cirratum*) and loggerhead turtle (*Careta careta*) (Jory and Iversen 1983, Iversen *et al* 1986). In release experiments using hatchery-reared conch, one of the most significant predators was the porcupine fish from the genus *Diadon*.

The preferred habitat for queen conch includes several grades of sediment with relative low relief such as fine-grained, coarse-grained, bio-turbated sands, and rubble. The sediment is often covered with macro-algae (Randall 1964, Alcolado 1976, Stoner 1994, Stoner and Schwarte 1994, de-Jesús-Navarrete *et al*. 1999, Delgado 1999). Higher relief habitats such as those occupied by octocorals and hard corals embedded in sandy habitats are also important. Shallow and deep water conch populations can be found associated with the leeward slope, or over rodolith beds (Appeldoorn *et al* 2003, Gómez *et al*. 2005). Figure 6 illustrates the various conch habitat types. In those sites that lack seagrass habitats or are considered as rare habitat, juvenile conch are commonly seen in back reef areas or in the broad reef lagoons. Considering the patchy nature of the conch habitats, it is expected that conch distribution exhibit an aggregated pattern. Glazer and Kidney (2004) hypothesized that current conch habitat associations may be an artefact of fishing pressure which has the effect of depleting conch from their preferred habitats where successful fishing requires less effort than in habitat that is less preferable.

For these reasons, when conducting queen conch underwater visual censuses, there is a need to gather information about the patchy distribution of available habitats and bathymetry (often accomplished using available benthic maps, as well as maps detailing bathymetry). Maps detailing resource use (e.g., location of the fishing grounds or the marine reserves/protected areas) represent important information to consider when conducting visual queen surveys. Aspects related to the generation and use of thematic maps including their interpretation is further discussed in the GPS (Global Position System) / GIS (Geographic Information System) section.

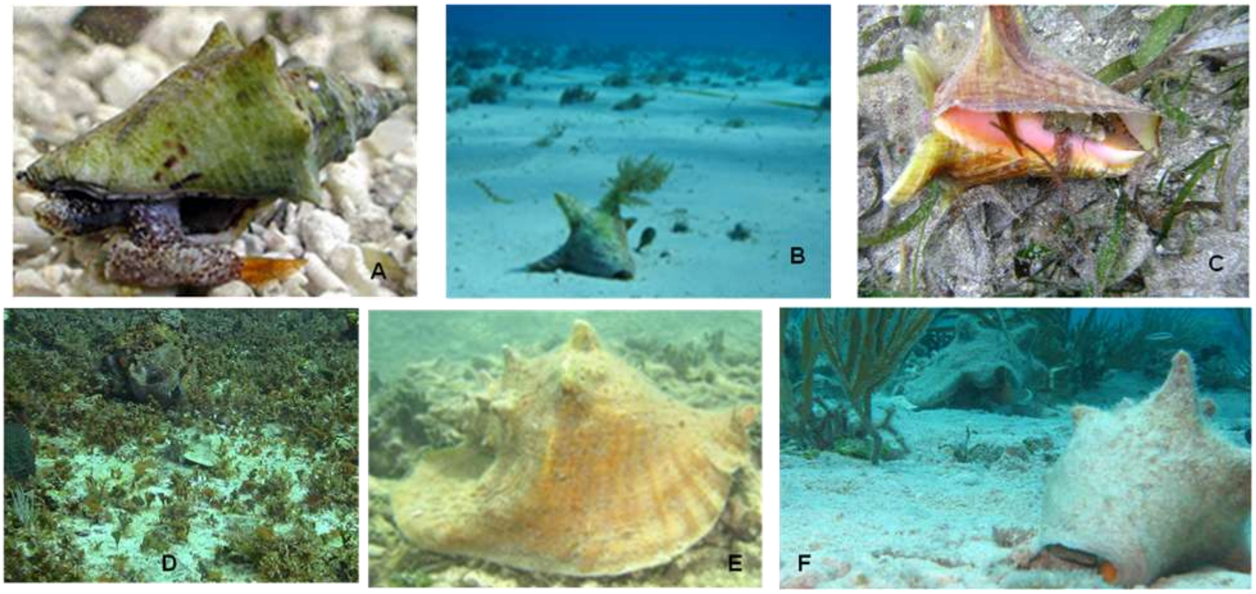

Figure 6: Examples of habitats occupied by queen conch throughout their ontogeny: A. coarse sand, B. Fine sand, C. Seagrass, D. Hard bottom, E. coral rubble, F. hard and soft corals. Pictures taken by Martha Prada, Heins Bent, Harvey Robinson, Barbara Reveles, and Megan Davis.

3.2. Use of GPS

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, it was made available for civilian use. GPS works in all weather conditions, anywhere in the world, 24 hours a day. In addition, there are other positioning systems such as The Russian Global Navigation Satellite System or GLONASS, the European Union Galileo positioning system, the Chinese Compass navigation system, and the Indian Regional Navigational Satellite System. Having a precise GPS system, surveyors can better locate the desired stations and then are able to compare spatial and temporal variations with lower errors than using other navigational approaches.

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's precise location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Modern GPS systems with distance measurements can determine the user's position and display it on the unit's screen or on electronic maps.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

Most handheld GPS receivers are accurate (25 - 6m), but the final accuracy will depend on the quality of the satellite signal that is received, and the availability of correction factors added to the original signal through additional antennas, differential beacons, or WAAS (Wide Area Augmentation System), among others. If WAAS correction is activated in the unit, it is possible to increase accuracy to 1-meter resolution in 97% of the cases. The accuracy of the GPS information is often based on a 50% to 60% probability, since there are factors that introduce errors (Table 2).

Table 2: Main sources and magnitude of GPS errors (from http://www.gpsinformation.org/dale/dgps.html)

Error	**Description**	**Value (m)**
Ionosphere	Region of the upper atmosphere, from about 85 km to 600 km altitude. It influences radio propagation to distant places on the Earth.	4.0
Clock	Time difference between internal clock and satellite clock utilized to estimate the user position. The clock varies among the GPS units.	2.1
Ephemeris	A model that estimates the GPS satellite positions and then used to estimate the user's position.	2.1
Troposphere	The non-ionized part of the atmosphere primarily composed of nitrogen and oxygen. The troposphere is a non-dispersive medium that can delay the signal travelling from the satellite to receiver.	0.7
Receiver	Varies depending on GPS unit	0.5
Multipath	Understood as the reflection of radio signals off surrounding terrain; buildings, canyon walls, hard ground, etc. These delayed signals can cause inaccuracy.	1.0
Total		**10.4**

When using a GPS unit, you need to understand the following concepts:

Datum, or the predetermined and fixed land-based references, utilized to calculate the shape of the Earth and therefore to later calculate the coordinate system of a particular point of interest. There are hundreds of datums developed for specific areas. The datum WGS84 is almost identical to NAD83 and is the only reference system of global reference.

The geographic coordinate system is the system that enables you to locate a position on the Earth by a set of numbers or letters. The coordinates are often chosen such that one of the numbers represents vertical position, and two or three of the numbers represent horizontal position. In this system, the Earth is divided by imaginary lines a few kilometres away from the centre except at the poles and the equator where it passes through the Earth's centre. Lines joining points of the same latitude trace circles on the surface of the Earth called parallels, as they are parallel to the equator and to each other. The North Pole is 90° N; the South Pole is 90° S. The 0° parallel of latitude is designated the equator, the fundamental plane of all geographic coordinate systems. The equator divides the globe into Northern and Southern Hemispheres.

The projected coordinate system is the coordinate system that transforms the 3D geographic coordinate system into 2D dimensional flat projected coordinate system using mathematical formulas. Map projections usually transform coordinates into conical, cylindrical, and planar surfaces. Depending on the projection used, some distortions may be observed, thus it is recommended to use the projection that minimizes that distortion. There is a need to transform the geographic coordinate system into a projected grid when calculating geometry of the map, i.e.: estimation of area, perimeter, centroid, etc. Geographic Information Systems (GIS) software easily performs this kind of transformation.

3.4. Geographic Information Systems

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all types of geographically-referenced information. You need a GPS to geo-reference your data, or to have geo-referenced maps to perform the necessary transformations. Generally, you design a GIS in response to your needs, thus several applications are utilized to make the data compatible. In a GIS you can view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

Data for GIS can be in two formats: vector graphic or raster images. In a raster image each spatial location is associated with a pixel, or a rectangular matrix of attributes indicating for instance the colour, the elevation, and ID number. Raster images are normally acquired by scanning, by a digital camera, or by a remote sensor mounted in satellites. Raster graphics are resolution dependent; they cannot scale up to an arbitrary resolution without loss of apparent quality (Figure 7).

A vector graphic uses mathematical algorithms to draw shapes using points, lines, curves, and polygons based on control points. Each of these points has a specific position on the x and y axes along with an associated attribute table. Vector data can be scaled up without losing resolution, and therefore is commonly utilized for map generation. Algorithms for manipulating and analyzing vector data are complex and may be processing intensive; however they require less memory compared to the analysis of a raster image (Figure 8).

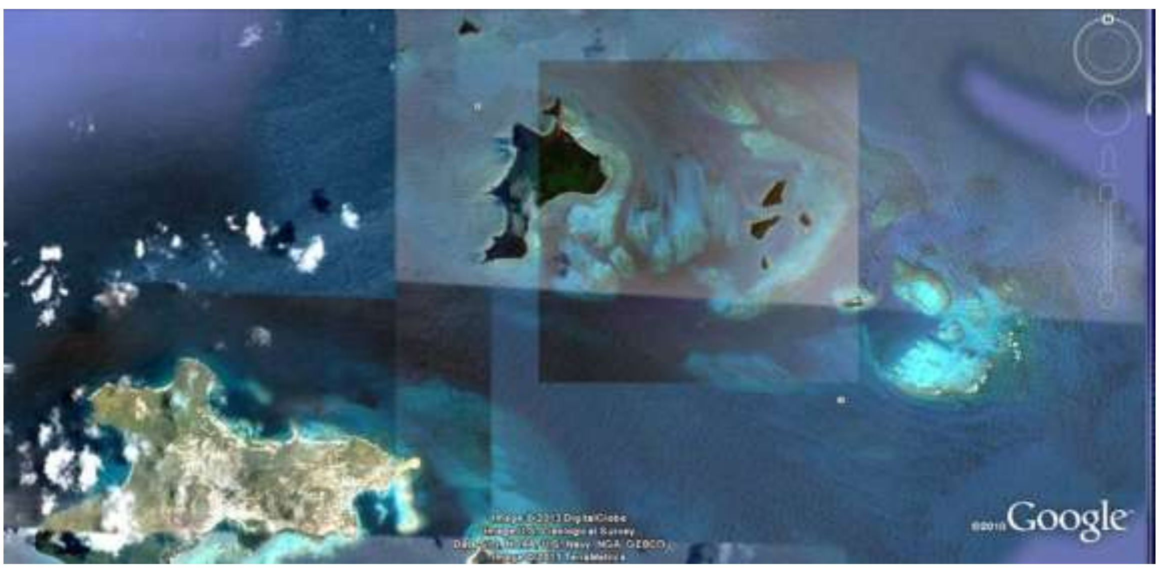

Figure 7: A raster image of the section of St Vincent and the Grenadines taken from Google Earth. Satellite imagery was taken in August 2005.

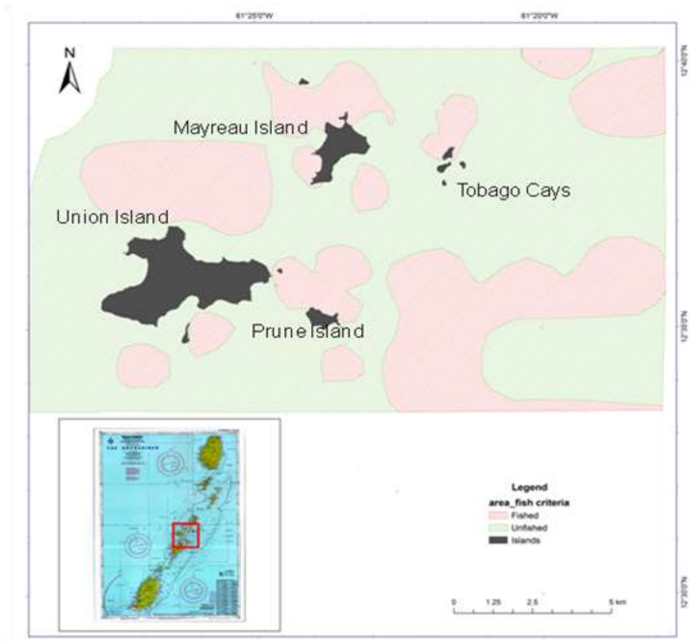

Figure 8: A vector map of the queen conch fishing grounds from a section of the St. Vincent and the Grenadines. Map generated in Arc View GIS utilizing data available in the MARSIS web database available from www.grenadinesmarsis.com

The University of Minnesota has developed a computer application that allows transfer (upload / download) data from Garmin handheld GPS receivers to GIS software through a USB / serial port connector. This is a free application call DNRGPS, and can be downloaded from http://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html.

The use of this application facilitates and improves data quality in the survey planning, for instance in the process of uploading coordinates of the desired station locations and then downloading the coordinates of the effective field station locations. With this application, it is also possible to download waypoints, tracks, and routes from Garmin GPS and save as ArcView Shapefiles or Graphics.

Arc GIS is one of the most common GIS software packages. It is powerful but also expensive (yearly licenses are required), thus it is not always available for its broad use. Fortunately, there are open source GIS software options that can be used. Among them is the Quantum GIS (QGIS), a user friendly program from the official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities. It can be downloaded from http://hub.qgis.org/projects/quantum-gis/wiki/Download. Another open source GIS is the so called gvGIS and is known for having a user-friendly interface, being able to access the most common formats as both vectors and rasters. This software can be downloaded from http://www.gvsig.org/web/home/gvsighome /view?set_language=en.

The underwater census for estimation of the queen conch abundance will require GIS applications to: a) develop stratified sampling protocols; b) determination of spatial distribution of conch juvenile and adult densities at the various strata selected; c) establish trends of conch abundance.

3.5. Sampling Design Considerations

As presented by Ehrhardt & Valle (2008), estimation of queen conch population abundance can be performed utilizing several protocols as follows:

Random protocol: This option considers stations selected randomly within the study area. This approach is not recommended since it is well known that conch aggregate in specific habitats and depth strata. The protocol is simple, and the calculations are also simple, however it is a method of low efficiency and precision.

Systematic protocol: This option considers equidistance and pre-defined distances among stations. Randomness is introducing when selecting the first station. Using this protocol, the entire area can be surveyed, but is possible to have data gaps depending on the location characteristics such as patchy habitat distribution, or the inclusion of sites beyond diving limits. Calculation of the population mean can be biased, which can be counteracted with a large number of stations. Another limitation is that there is no formula for calculating variances.

Stratified random protocol: This option allows the selection of stations using criteria affecting the abundance of the conch populations such as the spatial distribution of habitats, bathymetry, the location of fishing grounds, or the locations and patterns of protected areas. The applicability of this approach relies on the availability of the spatial information related to these criteria. Stations are apportioned randomly to the defined strata. When the study area lacks habitat maps, nautical charts are useful to define depth strata and aerial photographs or Google Earth images are useful to help define habitats in shallow waters. Experienced fishers can provide useful knowledge for complementing maps needed for identification of strata to be surveyed. It is expected that using this protocol will reduce overall variability; calculations of population mean will utilize weighted formulas.

Stratified random with replication protocol: Similar to the stratified random protocols, but includes additional stations randomly located within each strata, accounting for variability in populations that are not homogeneously distributed. For instance, the second order of stations can be allocated within conch aggregations.

Independent of the selected protocol, at each station the diver will count and measure queen conchs within a known area, either in a belt transect or in a rectangular or circular quadrat (Figures 9-10). The extension of the sampled area will depend on the local environmental characteristics. Usually belt transects are applied to broad shelf areas, whereas quadrats are applied to narrow shelf areas. It is expected that the areas surveyed will be around 500m^2 or more.

For larger areas, divers may be towed by vessels or use scooters to cover, especially in low density populations such as when conch populations have been decimated.

Figure 9: An example of simultaneous circular quadrat carried out by three divers. The circle size will vary depending on the site characteristics and the sampling design. Drawing by Diana Prada.

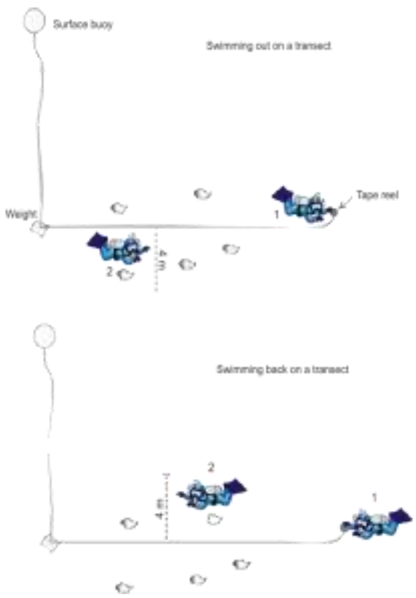

Figure 10: A belt transect surveyed by two divers. The length and width of the transect will vary depending on the site characteristics and the sampling design. Drawing by Diana Prada.

Glazer (1999) developed a protocol for sampling inside conch aggregations based on belt transects. Initially, a primary tape (usually 100m) is laid along a margin of the aggregation. Five randomly-placed belt transects extend 100m perpendicular from the primary tape. The belt transects bisect the aggregation and all conch are counted 1-m either side of each belt (2m total width). Data recorded includes size of conch (length for juveniles and lip thickness for adults), habitat along the belt, habitat that each conch occupies, location along the belt where the conch is found, and reproductive activity (mating and/or spawning.) The area of the aggregation is determined by swimming the perimeter of the aggregation using a GPS and using these points in a GIS to determine the area occupied by the aggregation. The product of the density estimations and the area of the aggregations provide an estimation of the total abundance of both adults and juveniles. The relationship between reproductive density and overall density is enumerated to help understand Allee effects in the Florida population.

During conch visual census, the diver at minimum should measure the following morphological features (Figure 11):

- Siphonal length or the length from the apex of the spire to the end of the siphonal canal using large calipers.

- Lip thickness or the thickness of the flared lip measured at the closest place to the last conch spire, using a small caliper.

It is expected that the combination of these two measurements can help discriminate between juvenile and adults conch. Initially, conch having a siphonal length larger than 200-220mm was believed to be adults; subsequently the concept of lip thickness was introduced. Adults (characterized by maturation of the gonads) are now defined by a minimum lip thickness of 5mm. More recent studies are reporting that sexual maturity is achieved when conch attain lip thickness. This corresponds to roughly 6-10 months after the initial formation of the flared lip (Egan 1985, Aldana-Aranda and Frenkiel 2005, Stoner *et al* 2012).

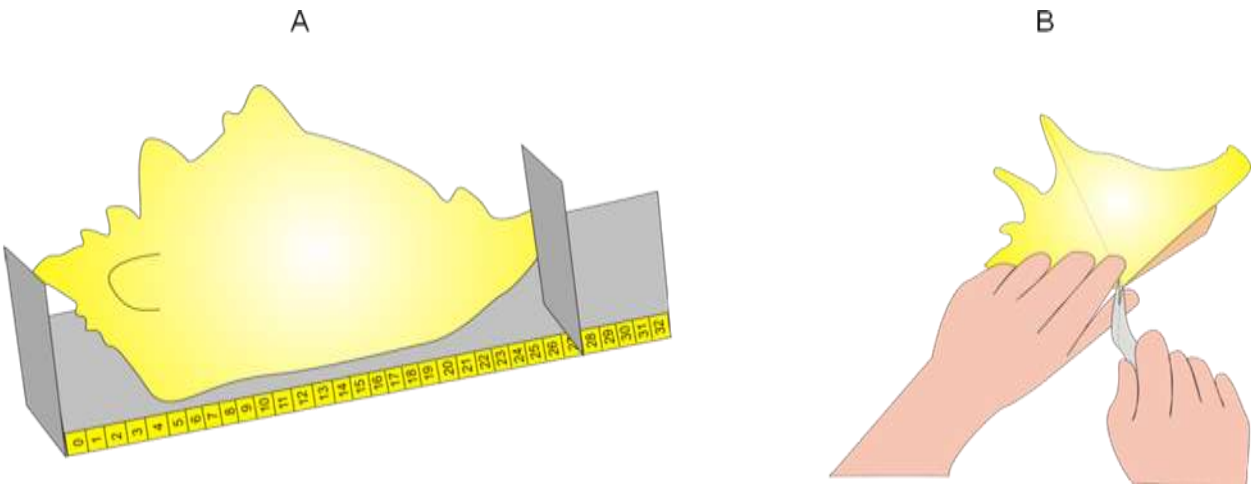

Figure 11: The two most common morphometric parameters for estimating the age of queen conch: A. Siphonal length, B. Lip thickness. Drawing by Diana Prada.

During underwater visual surveys, additional information on ecosystem characteristics may be collected, including for instance habitat type or quality. Data collection of other organisms may facilitate the examination of biodiversity. Conch tissues can be collected for genetic analyses.

Other information can also be collected from the sampling vessel including plankton trawls for larval conch abundance and/or distribution (or other components of the plankton). At a minimum, the following data should be noted during these surveys: a) observer name or code; b) Date, c) site name and GPS coordinates; d) average depth of the site; e) length or number of transects; e) siphonal length and lip thickness for every conch inside the transect; and f) predominant habitat type for the transect. Additional information may also be beneficial when examining the data. These include a) the estimation of conch presence or abundance outside the transect; b) identification of other conch species; and c) environmental characteristics such as water temperature, currents, weather conditions. These additional data can be useful in providing overall ecosystem-based information.

The relationship between conch length and weight is important when determining the overall biomass of the population. For this reason, other relevant information that could be collected is related to the conch length and conch weight (the entire animal). This relationship between these two parameters is necessary to determine morphological population characteristics and the growth equation parameters (the coefficient and the exponent included in the mathematical function describing the relationship between length and weight). When there is no conch length-weight relationship for the survey region, or when the relationship exists but has not being updated for several decades, re-estimation of those parameters is recommended. In this case, researchers need to collect a broad sample of conch including juveniles and adults, thus providing a comprehensive representation of the population thereby reducing the confidence limits associated with the parameters.

Conch measurements obtained by diving require experienced divers that can locate all conchs inside the sampled area including buried animals while adhering to safe-diving procedures. Annex 1 presents standards that promote safe diving procedures and protocols used for scientific diving institutions in the U.S.

Information about queen conch located beyond the safe-diving limits of SCUBA diving using ambient air (25-30m deep) need different approaches (Figure 13). One can be the use of a re-breather system. This is a system that recycles exhaled carbon dioxide by adding oxygen in a closed or semi-closed circuit. The re-breather system utilizes a mixture of gasses (oxygen, helium, nitrogen) to allow for deeper diving. A diver with a re-breather can usually go as deep as 200m, thus exceeding even the deepest sites within which conch are believed to inhabit (approximately 100-120m deep). The downside of this approach is the cost of the system, including training, along with the limited time divers have depending on the working depth.

Another approach is the use of a towed camera that can record video/photograph imagery along with GPS information. This approach provides real-time observation as well as an archival record for subsequent analysis. There are a variety of these towed system among them are:

Video cameras: such as Sea Viewer (www.seaviewer.com), a custom-built professional-quality camera system which can be used to take snapshots of one location or used for fast-trolling. These systems are available with optional LED lights, GPS video overlays and video recorders that are used in many different underwater applications. This system has been employed in benthic surveys of habitat in the Grenadines. It is also currently being employed in surveying deepwater conch populations in Florida.

Remote Operated Vehicles (ROV): a tethered underwater robot tethered via a communications cable to the surface. The system consists of cables that carry electrical power, video and data signals back and forth between the operator and the vehicle. Most ROVs are equipped with at least a video camera and lights. Additional equipment is commonly added to expand the vehicle's capabilities. These may include sonar, magnetometers, a still camera, a manipulator or cutting arm, water samplers, and instruments that measure water clarity, light penetration and temperature (Figure 12).

Autonomous Underwater Vehicles (AUV): This is a similar system to an ROV. In this case, the vehicle navigates underwater without requiring input from an operator. Hundreds of different AUVs have been designed over the past 50 or so, but only a few companies sell vehicles in significant numbers, including Kongsberg Maritime, Hydroid, Bluefin Robotics, Teledyne Gavia, and International Submarine Engineering (ISE) Ltd. AUVs carry sensors to navigate autonomously and map features of the ocean. Typical sensors include compasses, depth sensors, sidescan and other sonars, magnetometers, thermistors and conductivity probes (Figure 12).

Two parallel underwater laser pointers can be added to the video system in a way that positions the conch in the centre of the image, allowing for estimation of size. This is a distinct advantage over towed cameras. The laser photogrammetric estimations are more precise than visual estimates. Laser pointers are usually at sufficiently low power output of <5 mW which means that short, accidental exposure does not damage the eye (Rhoner *et al* 2011).

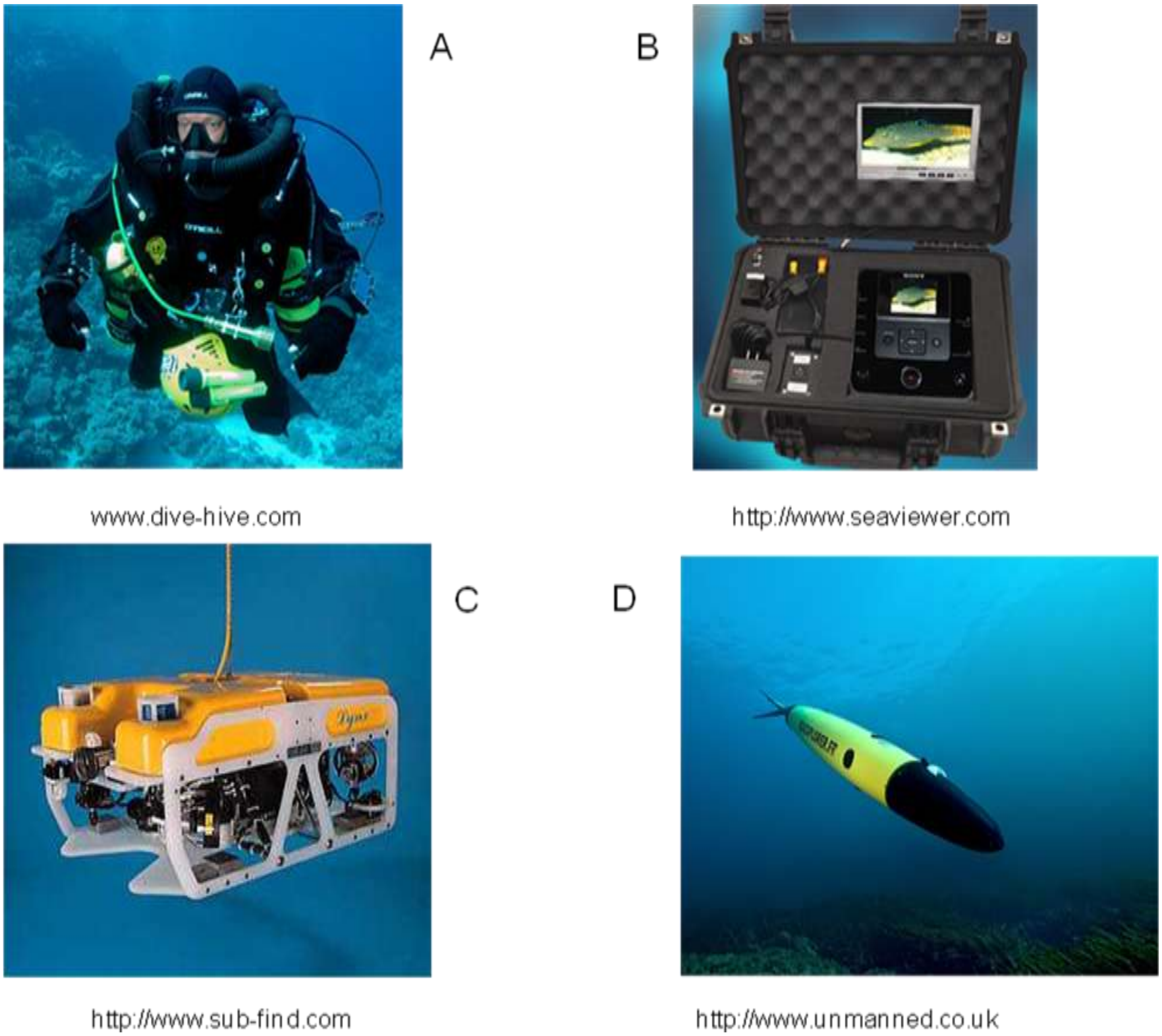

Figure 12: Examples of available technology for observing deep water fauna: A. Re-breather, B. Towed underwater video camera, C. Remote Operated Vehicle, D. Autonomous Underwater Vehicle.

3.6. Data Analysis

Once the underwater visual census has been concluded and the data has been entered and proofread, the next step is the process of data analysis to estimate sustainable levels of queen conch exploitation. This analysis involves a series of procedures and calculations that are presented below. These steps were adapted from analyses conducted in the Grenadines yet they have broad applicability.

1. Using Microsoft Excel®, select the entire data sheet, sorted from largest to smallest, thus ensuring that stations with no conch will be located at the end.

2. Create two new columns; one for juvenile conch and another adult conch. To discriminate between juvenile and adult conch, two criteria can be utilized: the LT (lip thickness) and the SL (siphonal length). Based on the LT criterion, recent studies have recommended that conch may still be juveniles if their lip thickness is < 15mm (Egan 1985, Aldana-Aranda & Frenkiel 2005, Avila-Poveda & Baqueiro-Cárdenas 2006). Alternatively, if SL is utilized, the average legal minimum size can be used assuming they are based on the level at which the 50% of the

population have reproduced at least once (Table 3). Therefore, adult conch should have minimum 19.6 cm SL (the average across all locations in Table 3). It is recommended to add 1-cm to this value to incorporate a 'precautionary' buffer. Excel filters, pivot tables or logical functions can facilitate this process of identifying juvenile or adult conch in the population.

Table 3. Summary of the minimum shell length stated in current fishing regulations.

Country	Fishing Regulation	Size (cm)
Antigua and Barbuda	Fisheries Act No 14 of 1983 Fisheries Regulation No 10 of 1990 Fisheries Act No 22 of 2006	18
Belize	Fishery Regulations of 2005	18
British Virgin Islands	Fisheries Regulations of 2003 Amended in 2002; 2007	17.8
Cuba		20
Dominican Republic	Law 64-00, Decree 833-03 of 2003, Law 307 of 2004	18
Grenada	Fisheries (Amendment) Regulations	18
Honduras	Ministerial Agreement 820/ 2003, 103/2005, 391/ 2006	22
Jamaica	Fishing Industry Act of 1975; 1976	22
Martinique	Regulation 994296	22
Nicaragua	Decree DGRN-PA-No 407-05 of 2005	20
Puerto Rico	Reglamento de Pesca de Puerto Rico 2010 No 7949	22.9
St Kitts/Nevis	Fisheries Regulation No 11 of 1995	18
St Lucia	Fisheries Regulation No 67 of 1987; No 9 of 1994	18
St Vincent/Grenadines	Statutory Rules and Orders Act Part 4 Sec 18 of 1986	18
Turks and Caicos		18
US Virgin Islands		22.9
Average		**19.6**

3. Using the Excel pivot table tool, in a new worksheet generate a Station Summary Matrix containing the following columns: site, lat, lon, X, Y, date, area surveyed per station, total conch, no. adults, and no. juveniles. Make sure that any label in the worksheet is larger than 6 characters.

4. Estimate the conch density per station by dividing the total number of conch by the total area surveyed for adult, juvenile and total conch. The following formula should be applied to estimate density:

$$d_s = X_s / a_s$$

Where:

x_s =Total number of conch found in the station

a_s = Total area surveyed per station

Remember, conch density will be calculated as ind/ha. Thus, there is need to express area in ha, for which you need to multiply values in m^2 given by the GIS by 10000. Save this file as a text file (CVS or comma delimited for instance).

5. Open QGIS and import the Station Summary Matrix text file from the layer menu using the Add Delimited Text Layer function. Choose the appropriate format of the text file. Save this project.
6. Generate a point thematic map to illustrate the conch abundance. Use graduated symbols and colours in a way the information can be easily interpreted with respect to density, for example.

7. Add background polygons/raster maps to the GIS project (e.g., MPA spatial layer, layer representing fishing zones, Google image.) Select the combination that is more illustrative and easy to understand. You now have the first product for your report.

8. Calculate the total area in the MPA layer (ha), for protected and not protected strata within the GIS.

9. Continue with a spatial join in QGIS, in the Data Management Tool menu. The target vector will be your point file; the join vector layer will be your MPA map. Create a new file and make sure to select "keep all records" in the output table option. Now you are ready to continue the analysis in Excel. (MPA will be the strata for the analysis, since there is not a detailed habitat map).

10. Once again, open the Excel file and call the new join file. Now every station has in addition information about stratum under examination.

11. Group the conch density by sampling strata, and, for each stratum, calculate the descriptive statistics. These parameters include average, variance, standard errors, confidence limits of the estimation, etc. Excel or any statistical program can easily perform these calculations.

12. Extrapolate densities from sampling stations to the entire surveyed area. To do this you will need to have the total area by stratum (previously calculated in the GIS application). Once area by stratum is obtained, there is need to estimate the proportion of each stratum area to calculate weighted densities, applying the following formula:

$$D = \Sigma\, d_e * (A_e / A)$$

Where:

A_e = Total area by stratum

A = Total area being studied.

d_e = Density by stratum

13. The sum of the weighted densities multiplied by the total area will provide estimates of the total population abundance.

14. Determination of overall fishing potential will be now examined against pre-established density reference points. The latest recommendations are based on the population density greater than or equal to 100 conchs/ha or higher if the spawning stock is included in the survey. This recommendation was adopted by the Queen Conch Expert Workshop, by the WECAF Queen Conch Working Group, and by CoP16, resolution "Regional Cooperation on the Queen Conch Management of and Trade". Lower densities indicate significant risk that reproduction, and hence recruitment will be impaired, and therefore special management measurements might be required. This reference point may change at different locations depending on site-specific information (e.g., reproduction at density). In any case, fishing is not advised if adult densities are less than 50 conchs /ha based upon a minimum threshold previously identified for successful queen conch reproduction (Stoner and Ray-Culp 2000). See more information about this recommendation in Medley (2005).

15. In those situations where queen conch population densities exceed the minimum threshold values detailed in 14 above, 8% of the estimated mean or median fishable biomass can be used to set a precautionary sustainable yield. To estimate the conch population biomass, it is necessary to generate a histogram with various conch size classes and then applying the following formula:

Biomass = ΣAL * WL

Where:

AL = abundance within each size class (total length)

WL = average weight within a given size class

To calculate the value of the WL, it is necessary to apply the length-weight relationship: Weight = $a*b^{Length}$, or, ln(Weight) = a + b*ln(Length). Table 4 presents parameters estimated for this relationship in several locations.

Table 4: Parameters for the relationship Weight-length at various Caribbean locations

Place	**Constant (a)**	**Coefficient (b)**	**Reference**
La Parguera, juveniles, Puerto Rico	-2.533	3.484	Appeldoorn 1991
Isla Caja de Muertos, juveniles, Puerto Rico	-2.232	3.200	
La Parguera, adults, Puerto Rico	-1.510	2.804	
Isla Caja de Muertos, adults, Puerto Rico	-1.590	2.783	
Vieques Island, adults, Puerto Rico	-3.708	2.583	
Pedro Bank, Jamaica	-4.29	3.14	Tewfik 1991

It is important to recognize that fishable biomass will only include conch in those size-classes within which fishing is allowed. Conch in size-classes for which fishing is prohibited is not considered part of the fishable biomass. In many locations, juvenile conch is not permitted to be harvested and would therefore not be considered as part of the fishable biomass.

16. Once the total conch biomass is estimated, the 8% harvest control rule can be applied, also following recommendations in the Regional Cooperation on the Queen Conch Expert Workshop. Additional restrictions should be applied to this calculation based on site-specific conditions (for example, how ‘open’ or ‘closed’ the population is).

Total Allowable Catch (TAC) will be the final recommendation for the fisheries managers and needs to incorporate a meat conversion factor for the different meat weight. The conversion factors are required because meat is trimmed to remove the intestines and other internal organs and the peeling of the darker portion of the outer “skin” to various levels depending on the consumer demands or cultural preferences (clean at 50, 65, 85 or 100%). This approach accounts for local consumption, and to define the final export quota.

Initial processing is completed by the fishermen, but final preparation for export is usually completed at a processing plant. The processing of the meat therefore requires a conversion factor in order to determine the real level of extraction at the population level as stated by Aspra *et al*

(2009). While overall consensus about how the conversion factors can be used and applied either for the entire Caribbean or for sub-regions, these authors proposed a conversion factor as presented in Table 5.

Table 5. Proposed conversion factors for queen conch meat to nominal weight. From Aspra et al 2009.

Processing grade	Conversion factor to nominal weight
Dirty	5.7
50% clean	9.5
85% clean	13.7
100%	16.3

17. The estimation of the final quota will need to incorporate additional restrictions depending on several criteria. One of them is the extent of the fishing bank. If the bank area is small, the potential to sustain fishing is reduced, thus requiring a downward adjustment of the estimated fishable biomass. Another aspect is the dependence of the conch population from external larval supply, a phenomenon which is difficult to validate. A number of pieces of evidence can be used to make this determination (see, for example, Delgado *et al*., 2008). Alternatively, the final quota can be adjusted upward if there are additional conservation measures such as the implementation of marine reserves with healthy, reproducing queen conch in dense aggregations. Additionally, a variety of conch ages should be present. The use of these strategies is all examples of good application of the precautionary approach towards sustainable fishing.

18. Once a final TAC is developed, fishery managers needs to calculate the local consumption to ensure that it is incorporated into the final export quota. International trade in queen conch is subject to CITES review; therefore, it is important to consider that CITES examines how each Party define its export quotas and if the Non-detriment findings are applied in the process.

3.7. Additional information

Geometric Morphometry

Additional queen conch population characterization can be obtained through geometric morphometry. This is a low-cost technique that facilitates analyzing phenotypic differences by looking at the variability of shapes based on reference points. The approach uses polygons centroid distances using the free software "**C**ollection of **L**andmarks for **I**dentification and **C**haracterization" or CLIC package (http://www.mpl.ird.fr/morphometrics) developed by J.-P. Dujardin from Institut de Recherche pour le Développment (IRD) in France. To confirm statistical significance of the results, additional statistical analyses using ANOVAs or multivariate analyses might be necessary. This modern morphometric tool can provide information on queen conch population growth or differences between ontogenetic stages. There are other free software packages such as TpsDig, TpsRelw, TpsReg, TpsUtil, TpsTr available from http://life.bio.sunysb.edu/morph/ can be also used for this type of analysis.

Reference points are obtained from a representative number of queen conch photographs that should be taken with the same focal distance, if possible with the same camera, and over flat surfaces, thus ensuring standardization. A total of 10 reference points for each picture is highly recommended (Edna Marquez, personal communication). One example of the use of geometric morphometry is presented in Figure 13.

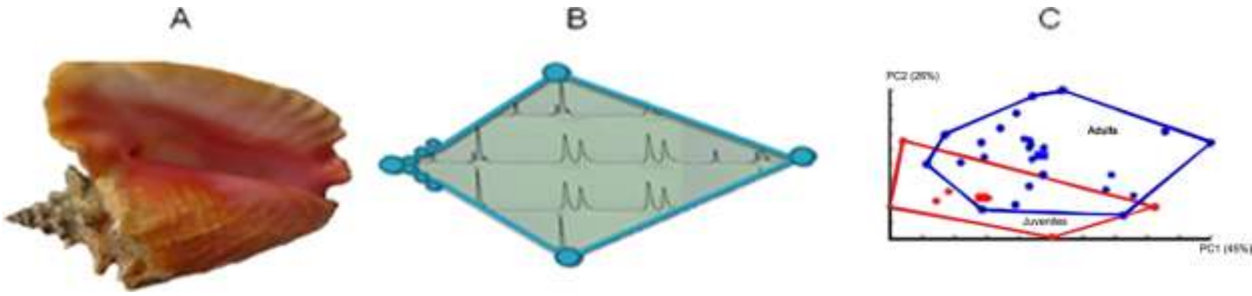

Figure 13: Use of geometric morphometry to estimate growth differences between adults and juveniles of queen conch populations in the San Andres archipelago, Colombia. Provided by Edna Marquez unpublished. A. Basic queen conch photograph, B. Reference points and polygon generation, C. Comparison of the results between juvenile and adults.

Plankton

Plankton samples can be collected during the field surveys and these samples provide additional information on the presence / absence, density, and abundance of veligers. The collection of the samples requires a 202 micron plankton net with a flow-meter attached in the mouth of the net (Delgado *et al* 2008). The flow-meter measures the volume of water that passes into the net thus providing density estimates of conch larvae (number of larvae/m^3). Depending on the local conditions, the plankton net can be towed between 15 – 30 min at low speed. The samples should be preserved in 70% alcohol or 10% formalin. Analysis of plankton samples continues at the laboratory where experts identify and quantify the plankton community. The use of plankton information is important to verify conch reproduction and to infer sources of conch larvae recruiting to the local population (for an application of this analysis, see Delgado *et al* 2008).

As previously discussed, the determination of a quota to sustain a queen conch stock may depend on the source of the larvae providing recruits to the population. If most larvae are coming from sources outside the stock, more relaxed regulations may be sufficient. However, if the source of larvae is primarily from the local population, regulations and/or quotas will need to be very conservative to ensure sustainability. Plankton sampling, genetic analyses, hydrographical considerations, and the time required for the recovery of a population may all serve as proxies for how 'open' or 'closed' a population is and, consequently, how conservative management must be. For example, in Florida, queen conch plankton sampling, drift vial studies, remote sensing information, and the time to for the population to recover suggest that the population may be closed and therefore more conservative policies are necessary to ensure the long-term sustainability of the population (Delgado *et al* 2008).

Genetics

There are currently several types of genetic approaches that can be used to examine the composition and origin of queen conch populations. These methods fall into two broad categories: DNA-based (e.g., microsatellites) and proteins (e.g., allozymes). In general, the method that examines proteins is much less expensive but it is also much coarser. DNA-based techniques have become less expensive and are more accessible due to the rapidly developing advancement in genetic techniques and tools. Prior to the wide use of these techniques, it was widely believed that larval transport facilitated the extensive exchange of genetic material over large distances and, therefore, the region-wide populations was well-mixed and uniform. Current interpretation of the results of a number of studies is contradicting those conclusions. For instance, in the case of San Andres archipelago, Marquez *et al* (in press) identified three different genetically distinct populations (Figure 14) that were explained by patterns in oceanographic (Landínez-García *et al*. 2009).

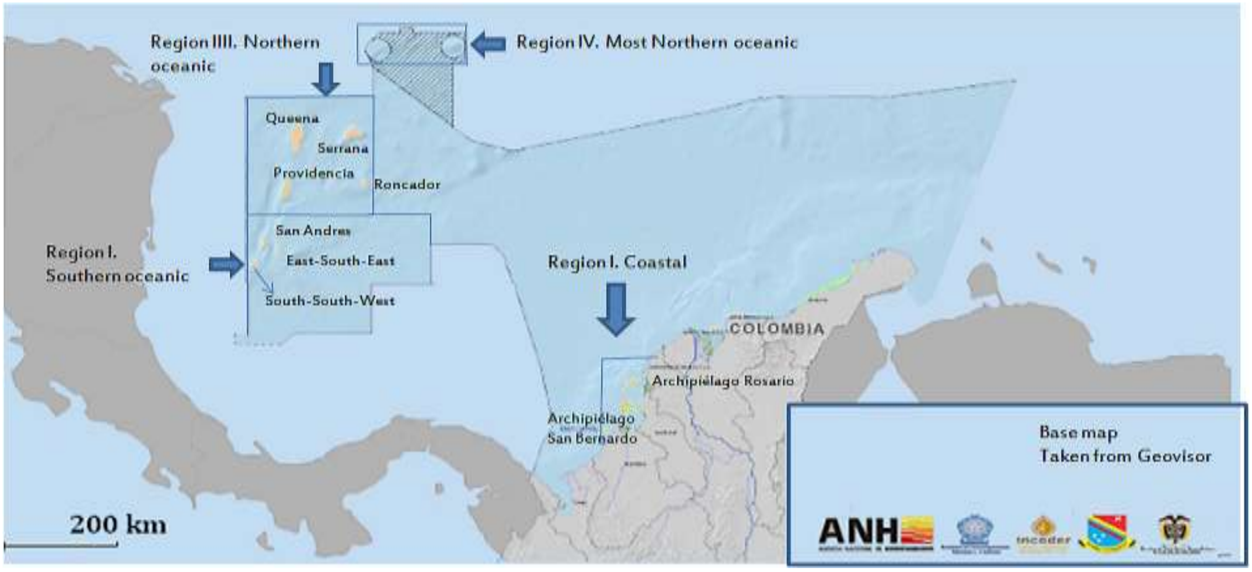

Figure 14: Location of different banks within the San Andres Archipelago, where several genetic and morphometric studies have been conducted. Marquez et al (in Press).

CHAPTER IV: ADDITIONAL CONSIDERATIONS ON PLANNING AND SURVEY DEVELOPMENT

Objective:

At the completion of this chapter, trainees will be in better position to plan and develop a scientific survey program to study the spatial distribution and abundance of queen conch and of integrating criteria to avoid negative outcomes.

4.1. Introduction to developing a survey program

Information presented in this section complements the theoretical concepts developed in previous chapters, particularly related to the recommendations needed to plan, organize and develop queen conch visual surveys. Therefore, this chapter includes recommendations related to the selection of a team, identification of their role, and decisions about the survey approach following the steps detailed in Figure 15.

Survey planning usually begins with the institutional (fishery or conservation agency) decision to conduct a scientific expedition and to clearly establishes its objective(s). The early establishment of achievable objectives with available resources is critical for the clarity of purpose within the survey team, for ensuring that the priorities of the funding agency are addressed, and to achieve and maintain the broad support of the resource users and the general public. For example, divers need to follow the planned protocol, and not diverge to secondary objectives; and boat captains need to put divers in the correct locations. Data should be backed-up without exception, safe-diving should always be exercised and statistical and GIS input about number and location of the stations should be performed correctly.

Achievable objectives will be based on the availability of financial, technical, and human resources, and the ability to leverage these resources by developing effective partnerships with local, national or international partners. Timelines should be identified early in the planning process.

A well-developed team is critical to ensure an effective sampling program. Therefore, emphasis should be placed on the selection of the expedition coordinators including a chief scientist, logistical coordinator, divemaster, boat captain, and a group that comprises the core survey-planning team. The core team is responsible for identifying appropriate field work methodologies, achievable timelines, and protocols built on a full review of all available information concerning the area of interest. Local fishers may also be invaluable when developing a robust and comprehensive team because their knowledge of the spatial distribution is invaluable when identifying areas to be surveyed.

Even though the team should have developed approaches for the surveys, they must also be sufficiently flexible for issues that may arise. For example, maps may not accurately reflect bathymetry thus making safe-diving at the predetermined site impossible. Additionally, inclement weather may impact the timeline thus necessitating changes in sampling schedules. The goal should be the need to make ad hoc changes to the sampling program during the survey. In general, anticipating problems may increase the ability to improvise efficiently during the surveys.

It is recommended to have this plan in writing, and give a copy to every individual participating in the survey; sometimes this document is required to obtain necessary survey permits.

Figure 15: Steps in planning and conducting a fisheries independent survey program for queen conch. The roles and functions of various members of the conch survey team are associated with the specific activities.

4.2. The survey team

The development of an underwater visual census requires assembling a multi-disciplinary team with expertise and experience relevant to the survey program priorities. The survey development process consists of three phases: planning, development, and data analysis and reporting. It is important to ensure that individuals who are familiar with each stage are part of the team. The ability to interact and communicate within a group is a concern mainly during the field work phase, and it is key in the successful completion of the mission. Remember people will be onboard of a sampling platform (sometimes small), working hard during consecutive days and perhaps and under risky conditions. These factors may generate special reactions and emotions that need to keep under control.

As presented in Figure 15, the entire survey team with eight principal roles: the chief scientist, the logistics coordinator, the dive coordinator (or divemaster), the boat captain, the observers, the data analysis group the GIS and Statistical experts, and the communication coordinator. Each role particular responsibilities as described below.

Chief scientist: The Chief Scientist is the person responsible for all the scientific work of the survey. Additionally, this person or persons should offer guidance and training for the working group. The chief scientist will respond to government or private institutions and is responsible for the overall data analysis and reporting. To assume these responsibilities the chief scientist should be qualified on several aspects: broad scientific knowledge, experience to attend field work eventualities, good communication skills and amenable to consult with relevant personnel, and various sources of information when necessary. The chief scientist is in charge of defining the appropriate survey data storage protocols.

Logistics coordinator: This is the person in charge of the logistics for the survey, during all three phases: planning, developing and analysis. Logistic is a broad term that refers to issues including travel, accommodations, availability of food, ensuring dive supplies are available and have been ordered as requested by the chief scientist, among others. The logistics coordinator interacts with the scientific personnel and the operations personnel.

Dive coordinator: This person needs to be a certified dive instructor or divemaster from an accredited diving accreditation organization. Preferably, they will be familiar with the area to be surveyed. They will ensure that all necessary dive gear is available and appropriate for the surveys approaches. Most importantly, they are responsible for ensuring that safe diving operations are conducted. In larger operations, this person is responsible for ensuring that the equipment is maintained and safe. They should record dive profiles including air consumption. It is highly beneficial if the divemaster is familiar with scientific diving and the needs to sometime make changes to dive plans as conditions warrant those changes.

The Dive Operator is often the dive shop who contracts the vessels and provides a captain for these operations. This person should produce a dive safety plan identifying diving protocols in case of any emergency, actions taken to maintain safety during the survey, and include the contact information for immediately communicating rescue resources available in the area. All divers should be insured in the case of an emergency (special dive insurance is available). Dive insurance providers needs to be contacted ahead, thus the dive safety protocol can be properly revised and checked.

Field personnel: These are the certified divers responsible for the actual data collection. Scientific divers must be comfortable and be able to: a) work long periods in the water; b)identify queen conch including both adults and juveniles and take high-quality data;, c) use dive equipment/instruments, d) maintain buoyancy to ensure sampling efficiency, and e) know how to respond to changing weather conditions. The divers are responsible for entering their own data into the computer, and to conduct quality control procedures prior to beginning the data analysis phase (i.e., proof read the data). A valuable plus of the diver is their knowledge in taking good underwater photographs. It is also advisable that they use their own equipment or have time to familiarize themselves with the equipment they will use, and how to maintain it is safe working condition. In those cases where advanced underwater survey approaches are employed (e.g., mixed gas diving), specific skills and training are absolutely necessary. If the survey uses deep diving, divers must have specific training and enough experiences to work under those conditions. Surveys employing using underwater video approaches may not need to dive much, but they must be comfortable with technical equipment and video equipment. It is advised that all participants are trained in first aid, cardio-pulmonary resuscitation, and oxygen administration.

Data Analysis Team: This is a group lead by the chief scientist and comprised of a good representation of the field personnel, along with other biologists and GIS and Statistical experts whose will be responsible for the analysis and reporting phase of the project. In many cases, it may be advisable to add an external scientific advisor who is familiar with developing the appropriate sampling methods prior to the survey, and consult on the appropriate statistical analyses after the surveys. The independent advisor can help in the verification of conceptual issues, data treatments and analysis, making sure the best available information is always utilized. The data analysis group should generate management scenarios and provide recommendations that have robust precautionary principles integrated into the analyses. Several proprietary computer software programs can be used for this purpose including the open source program open refine (http://openrefine.org/).

GIS and Statistical Experts: From the analysis group, the participation of a statistician is of great relevance. This expert should have a strong background in sampling methods and statistical analysis is invaluable in setting up the sampling design for maximum efficiency and to reduce variability. This person can use data from surveys either in the area where the program will be conducted, or data from other locations, to determine sample size and sample protocols.

The GIS specialist will participate in the spatial analysis, and generate maps needed to graphically present results, thus facilitating the interpretations and conclusions of the results. In some cases, this person can also advise on additional computer issues and software formatting, relevant when using different operating systems, software versions, or specific software demands.

Communications coordinator: The role of a communication coordinator is to contribute to the survey divulgation, by revising the wording utilized in the scientific reports, thus they can be easily understood for the general public. This step is important especially when delivering the survey conclusions and recommendations to the people taking final decisions on resource management, and consequently planning actions needed to accommodate the survey recommendations. The communication coordinator is also responsible in the establishment of the communication protocols during the field work.

The fishery / conservation led authority and their partners are the authority(ies) that initially determine, because of the great responsibility involved at this level, the most appropriated strategy is to assemble strong partnership locally, nationally or internationally if necessary.

Once data analysis is concluded, and prior to draw final conclusions and recommendations, a workshop with the people having good local knowledge of conch distribution and abundance, is highly recommended. This strategy opens the door to share results between scientific protocols and the traditional knowledge, providing an additional space for results analysis and to increase trust among these two groups.

4.3. Survey preparation

Several issues are considered in this section. The first one is related to the survey methodology.

The survey methodology should be based on a number of practical considerations besides those based on statistical design. Perhaps most importantly, the depth of the surveys will determine what methods are practical (Figure 16). Beyond safe diving depths will require either cameras or divers trained in deep diving techniques as described in previous sections. The determination of safe-diving depths should be made by the dive coordinator in association with the chief scientist.

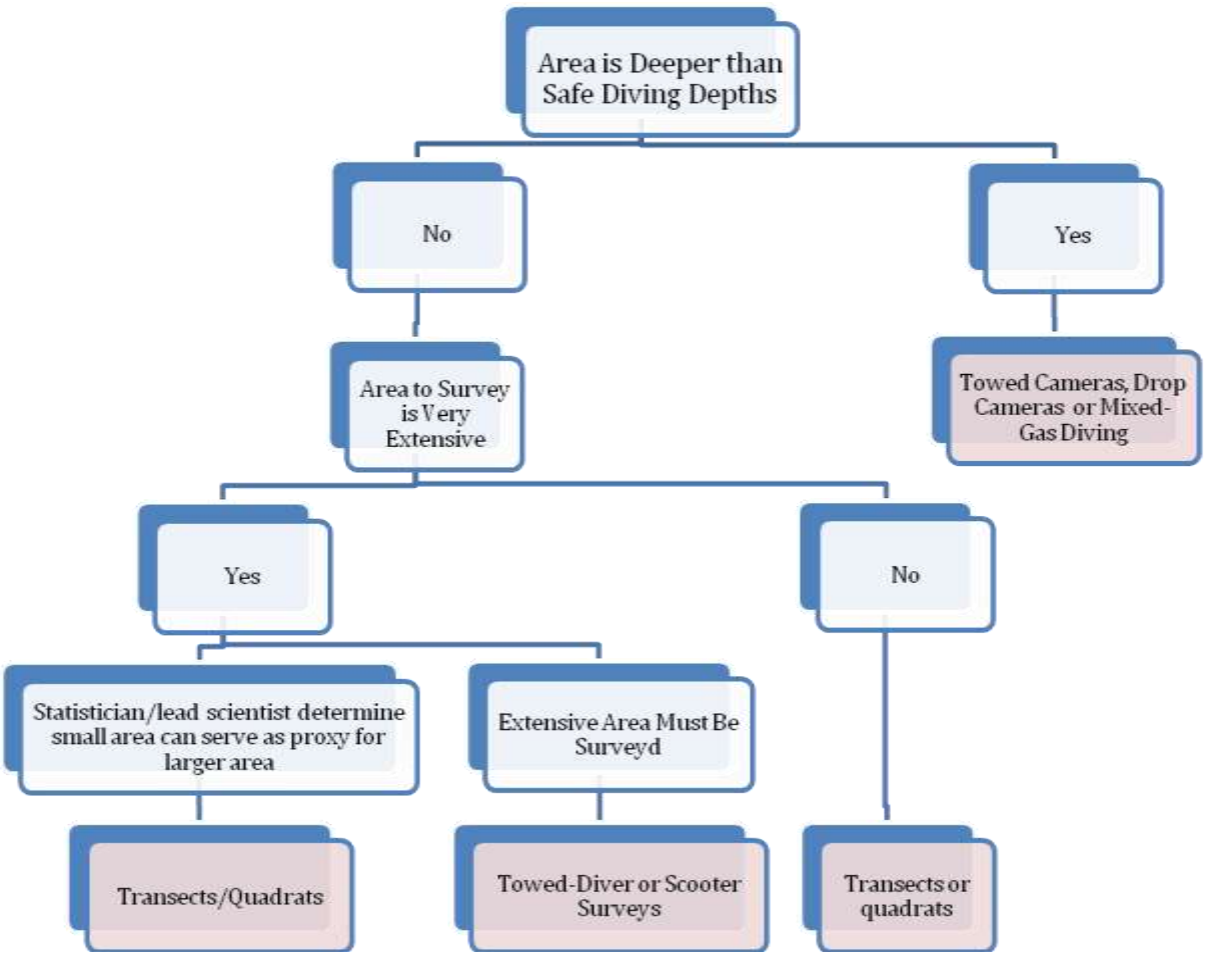

Figure 16: Guide for determining sampling approaches for queen conch fisheries independent sampling.

The decision about the overall area to be surveyed is part of the survey methodology. This determination should be made by the statistician in association with the chief scientist, considering the survey objectives. For example, if the goal of the program is simply to determine ecological associations rather than fisheries quotas, small, directed surveys can achieve the goals. Surveys that are focused on these small ecological questions are not addressed directly in this section; however, the approaches and team structures remain similar.

This notwithstanding, a majority of surveys is focused on determining overall density and / or abundance of a population. The chief scientist (perhaps in association with an independent statistical advisor) determines if a small area can be surveyed that will be a suitable proxy for the larger area. Usually, it is recommended that many small transects are preferred over fewer larger transects because the increase in replications will reduce the variance. In general, these methods are more intensive yet smaller in spatial scope such as using transects or quadrats.

On the other hand, if the statistician determines that more extensive areas need to be surveyed, methods that cover larger areas may be required. These methods cover larger distances and / or areas. Most surveys that have addressed this issue have used towed divers, divers using scooters, or towed cameras. The reader is directed to the review of fisheries independent sampling methods associated with this manual, and to look in Chapter III of this manual for more specific details on the surveys.

The survey sample size will determine the uncertainty related to the estimation of the population. The total abundance $\hat{\tau}$ of the population can be determined using the equation (Mendenhall *et al*., 1971):

$$\hat{\tau} = N\bar{y} = \frac{N \sum_{i=1}^{n} y_i}{n},$$

Where

$\hat{\tau}$ = Estimated population abundance

N = total number of transect

$\bar{y}$ = mean density per transect

The estimated variance on $\hat{\tau}$ is then based on both the variance within the estimate of $\hat{\tau}$ *as well as* the amount of area sampled relative to the entire area under consideration. This is calculated as:

$$\hat{V}(\hat{\tau}) = N^2 \frac{s^2}{n}\left(\frac{N-n}{N}\right),$$

Where

$$s^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})}{n-1}$$

and,

$\hat{V}(\hat{\tau})$ = Estimated variance on the total population

N = Total area available

n = Area sampled

s^2 = variance of sample

If preliminary surveys have already been conducted, the data may be used to develop a power analysis. Using this tool, an evaluation of the number of surveys that will need to be completed with an acceptable amount of error can be determined. The relationship between the number of surveys and error can be visualized in Figure 17. In general, the relationship indicates that a large number of surveys need to be completed in order to reduce the standard error to very low levels. In those cases, the survey design team may determine accept a higher standard error (more uncertainty) given logistical considerations. For more information on conducting these analyses, please see Zar (1999).

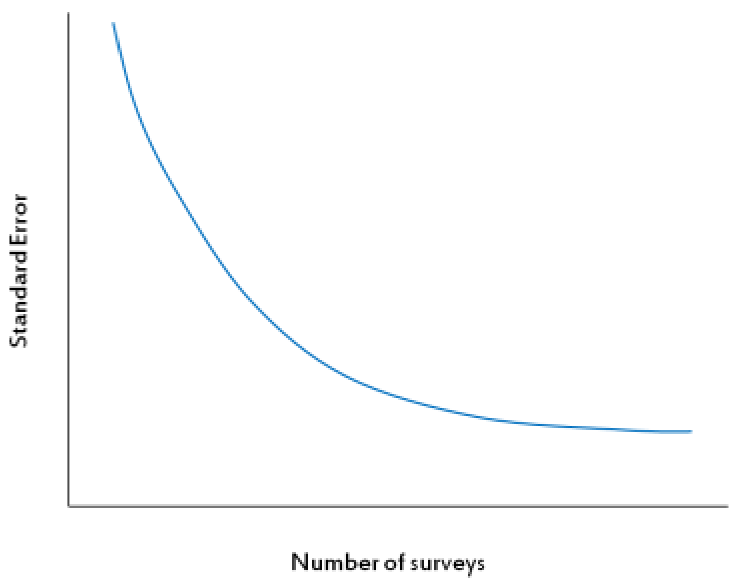

Figure 17: The theoretical relationship between standard error of the mean and total number of samples that need to be conducted.

A second consideration when planning a survey is the selection of the working platform. Several criteria should be considered here:

- A boat sufficiently sized to conveniently and safely deploy divers , fit the entire working team including crew and the dive safety personnel, along with the necessary dive and other scientific equipment and tools,

- The boat has all required documentation, and minimum equipment for safe navigation and communications,

- If necessary the boat has sufficient capacity to carry additional small vessels in the event they are needed for the surveys.

The third aspect in the survey planning phase is the development of a detailed survey plan. This is a document that compiles the various aspects of the survey containing information about:

- List of the participants along with their emergency contact information, affiliation, and certifications,

- The description of the working platform including its technical characteristics,

- A copy of the valid boat certifications and documentation,
- A statement of the survey objectives and a description of the sampling methods, listing the scientific equipment to be used,
- A detailed timetable,
- Location of the anticipated sampling sites (GPS coordinates and complementarily maps).

In addition to the survey plan, another relevant document is the dive safety plan. As mentioned before, this dive safety plan summarizes protocols to follow during diving activities, precautions taken to increase safety at sea, and protocols to follow in case of dive emergencies. Some countries require the processing of scientific permits, therefore the availability of a survey plan and a dive safety plan are always good advice to have ready.

The last aspect of the survey preparation refers to the communication protocols, particularly related to those that will be generated from the daily field activities. There is need to clearly define what kind of information, and when and where those communications will be delivered. The communications protocols will be agreed upon among the survey participants, and will depend on the availability of communication capabilities. In remote areas where access to VHF radios is difficult, long-distance radio, renting or buying a satellite telephone is advised.

4.4. Survey development

During the survey development, the core team will define activities to be conducted on a daily basis and assure this plan is known and understood for the rest of the field personnel. Daily plans would be based on the updated wind, wave height, currents, tides forecast and other marine weather reports available for the working area. A number of sources are available to consult for immediate recognitions of conditions including the following websites:

http://www.windfinder.com/

http://www.nhc.noaa.gov/

http://marquitosweather.com/

http://www.intellicast.com/

http://www.intellicast.com/

Because the field work is dynamic and need to respond quickly to environmental conditions, or any other eventuality, coordinators are force to plan in advance for those changes. Access to nautical charts and precise GPS units are both important to respond to rapid changes in daily plans.

Observers should digitize their data, which include the queen information, along with the GPS tracks and waypoints, and pictures. The chief scientist compiles the data and proceeds with the data back-up protocol.

The dive coordinator is responsible for the daily verification of the diving gears proper functioning, making the adjustments when necessary.

The boat captain is responsible for the safe and efficient functioning of the working platform, the provisioning of fuel, and to emergency equipment for both vessel repair and first aid.

The logistic coordinator makes sure that food, and drinking beverages are on board, in enough quantity and responding to special participants demands.

The communication coordinator circulates daily information notes, and responds for other communication strategies.

As mentioned in the introduction, these protocols are mean for broad guidance and particular situations may require different responsibilities and personnel structures.

4.5. Final products from the surveys

Upon completion of the survey and data analysis, the lead scientist is responsible for writing the survey report. The report is expected to contain the following sections: (a) introduction; (b) description of the survey area; (c) a summary of the methodology including field work protocols as well as data analysis approaches; (d) results presenting expected conch densities, population abundance, spatial distribution of adult and juvenile conch, including the statistical and GIS products, and the determination of the TAC if population densities meet the predefined minimum threshold; (e) data analysis relative to fishing criteria and comparisons with previous studies / different areas; and (f) conclusions and recommendations.

A well-written report should be clear, well-organized, have simple figures and maps and be accessible to non-scientists (e.g., politicians, managers, other stakeholders). An executive summary is often valuable as an overview of the project including brief bullets related to all the sections of the report. Depending on the needs of the management authority, this section may include recommendations.

CHAPTER V: PRACTICAL RECOMMENDATIONS

Objective:

By following the recommendations in this chapter, trainees will understand how to maximize the survey effectiveness, increase safety at sea, and integrate quality control procedures.

5.1. Working Platform

- When possible, use a working vessel with efficient and reliable engines thereby reducing fuel consumption and surveys costs,
- Ensure the vessel has been maintained regularly thus reducing risk of having problems at sea.
- Vessels should have a depth sounder, and GPS to support the scientific work.
- The captain should be well-versed in the use of GPS for navigation, marine radio.
- Keep on board a printed copy of the nautical chart with identification of survey stations.
- If applicable, upload to the GPS unit the entire set of field stations, thus they will available when field plans need to be adjusted.
- Choose captains and crews that are familiar with diving activities.

5.2. Scientific work

- Conduct training both onshore and in the field using the methods that will be utilized during the surveys. This will reduce variability associated with data collection. The training should include how to identify conch in the field (including those that are buried), measure conch, methods to deploy the transects, and other activities that may be part of the specific survey.
- Prepare a detailed checklist of items needed for day-to-day operations. An example of this kind of check list is presented in Annex 2.
- Keep back-up scientific instruments and equipment, in case of malfunction or if a piece of equipment is lost. These include for instance: pencils, plastic boards, rubber bands, GPS, batteries, calipers meters, metric tapes, additional weights, radios, etc.

- The use of special underwater paper is highly recommended although some survey groups prefer underwater slates.

- Ensure that the team is suitably trained in first aid with an emphasis on diving accidents or other common accidents which may occur in marine environments (e.g. venomous stings, allergic reactions). Oxygen administration and CPR training is highly recommended.

- File a daily float plan so that someone on shore is knowledgeable about the location of the surveys occurring that day and what time the team is expected to return to the dock. In some cases, notification should be sent to the relevant port or coastal enforcement authority. This may be especially appropriate during surveys that may enter fisheries excluded zones or in cases where the activities can be interpreted as illegal by individuals not familiar with the surveys.

- Mark all scientific tool / equipment especially if you are belonging to different agencies / persons.

- Train observers in general underwater concepts and try to have at least one underwater camera during each dive.

- Download and digitize field data on a daily basis, and establish a protocol to create a data back-up system.

5.3. Diving Activities

- Prior starting the survey program, perform a dive check-out to verify that the dive gear is safe and works properly and that the diver to whom the equipment is assigned is comfortable with its use. This is especially critical if the gear is not the diver's own.

- Mark all dive equipment and assign responsibilities for its proper use and care.

- Utilize two buoys, one to mark the station and another for divers to carry when expose, strong currents or low visibility conditions prevail.

- Keep on board additional dive materials and equipment. For example, a 'save-the-dive' kit should include extra max and fin straps, o-rings, silicon lubricant, regulator wrenches).

- It is strongly recommended that all divers have a review of their condition by a physician along with a certification of fitness to dive. The physician should carefully review any past medical issues and be familiar with bariatric medicine. This recommendation is, of course, difficult to achieve in many small island states, but should be achieved if possible.

- Have a dive master onboard to oversee and help in the diving activities in case of need when relevant. Large operations require greater capacity; small surveys with only 2 or 3 individuals onboard will likely not have the luxury of a divemaster different from the team.

- Obtain detailed contact information for each diver in case of any emergency.

- Make sure that all divers know how to use the Oxygen kit available on board.

We hope that information presented in this manual is

Useful in looking for ways to improve your Queen conch populations.

Good Luck!!!!

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ANNEX 1: Checklists for Queen Conch Fisheries Independent Surveys

Pre-survey Checklist

1. Survey Equipment

- ☐ GPS
- ☐ Tape measures (50m - or 100m) if conducting surveys using transects or quadrats
- ☐ Weights to attach to the tape measures
- ☐ Underwater Paper or Slates
- ☐ Underwater Pencil with replacements

Callipers

- ☐ Large (overall length)
- ☐ Small (lip thickness)

2. Dive equipment

- ☐ Mask, fins, snorkel
- ☐ Buoyancy compensator
- ☐ Weight belt
- ☐ Dive computer (preferably) or depth gauge

3. Safety Equipment

- ☐ Whistle, dive sausage
- ☐ Oxygen canister with mask

4. Analyses

- ☐ Computer with standard spreadsheet programs
- ☐ Software to and cable to download data from t GPS (e.g., DNR GIS)
- ☐ Cable for downloading GPS data
- ☐ GIS software

The American Academy of Underwater Sciences
STANDARDS FOR SCIENTIFIC DIVING

AAUS • 430 Nahant Road, Nahant MA 01908-1696

FOREWORD

Since 1951 the scientific diving community has endeavored to promote safe, effective diving through self-imposed diver training and education programs. Over the years, manuals for diving safety have been circulated between organizations, revised and modified for local implementation, and have resulted in an enviable safety record.

This document represents the minimal safety standards for scientific diving at the present day. As diving science progresses so shall this standard, and it is the responsibility of every member of the Academy to see that it always reflects state of the art, safe diving practice.

American Academy of Underwater Sciences

ACKNOWLEDGEMENTS

The Academy thanks the numerous dedicated individual and organizational members for their contributions and editorial comments in the production of these standards.

Revision History

April, 1987	
October, 1990	
May, 1994	
January, 1996	
March 1999	Added Sec 7.6.1 Nitrox Diving Guidelines. Revised Appendix 7 and 11.
January 2001	Revised Section 1.23.1 DSO Qualifications. Revised Section 5.31.4 Emergency Care Training. Revised Section 6 Medical Standards. Made Sec 7.6.1 Nitrox Diving Guidelines into Section 7. Added Section 8.0 Scientific Aquarium Diving. Moved Section 7.0 to Section 9.0 Other Diving Technologies.
April 2002	Removed Appendix 7 AAUS Checkout Dive and Training Evaluation. Revised Section 5.33.3. Revised Section 4.23.2.
August 2003	Section 1.27.3 Delete reference to Appendix 9 (checkout dive). Section 1.4 Remove word "waiver". Section 2.21 Change "supervisor" to "lead diver". Section 2.72.2.1 Remove reference to Appendix 13, and remove Appendix 13. Replace with "at www.aaus.org" after Incident Report. Section 3.28.3 Remove Appendix 10 (dive computers). Section 5.32 Training and 100-hour requirement, eliminate "beyond the DIT level". Section 5.32.1 Eliminate paragraph "Suggested topics include" and replace it with a list of topics for inclusion in the 100 hours. Some of these topics would be designated "R" (required). Section 4.0 Remove lead sentence "This section describes for diving". Alter the lead sentence read as follows: "This section describes training for the non-diver applicant, previously not certified for diving, and equivalency for the certified diver." Section 4.3 Delete this section. Section 9 Update Required Decompression (9.10) and Mixed Gas Diving (9.60) to individual sections. Appendices 9, 10, 11,and 12 Remove these and make available online as historic documents in the Virtual Office. Formatted document for consistency. Separated manual into two volumes. Volume 1 and the appendices are required for all manual and Volume 2 sections only apply when the referenced diving activity is being conducted. Volume 2 is where organizational specific information is contained.
October 2005	Section 11.70 Deleted section for rebreathers. Section 12.00 Added new section for rebreathers.
March 2006	Section 13.00 Added new section for cave and cavern diving. Section 11.5 and 11.6, revised definitions for Hookah and surfaced supplied diving.

April 2006	Section 5.30 Deleted emergency care training prerequisite. Section 5.50 Added emergency care training requirements to Continuation of Certificate.
November 2006	Section 2.60 flying after diving rules updated to meet current DAN standards. Section 3.20 dive computers reference changed to “appendix 8”. Section 3.60 air quality guidelines updated to meet current CGA standards. Section 5.30 – added words “Transect Sampling “to item #9. Appendix 1 – Updated one medical web link. Appendix 2 - Added the abbreviation “DO” to the MD signature line. Appendix 6 – new LOR template. Updated and added Appendix 8 dive computer recommendations Added Appendix 9 (criteria for entering diving statistics).
December 2009	Appendix 2 – Revised
December 2011	Section 6 – Revised and updated after medical review panel suggestions Appendix 1 – Revised Appendix 2 – Revised Appendix 3 – Revised Appendix 4 - Revised

CONTENTS

Volume 1

Sections 1.00 through 6.00
Required For All Organizational Members

SECTION 1.00 GENERAL POLICY

1.10 Scientific Diving Standards

Purpose

The purpose of these Scientific Diving Standards is to ensure that all scientific diving is conducted in a manner that will maximize protection of scientific divers from accidental injury and/or illness, and to set forth standards for training and certification that will allow a working reciprocity between organizational members. Fulfillment of the purposes shall be consistent with the furtherance of research and safety.

This standard sets minimal standards for the establishment of the American Academy of Underwater Sciences (AAUS) recognized scientific diving programs, the organization for the conduct of these programs, and the basic regulations and procedures for safety in scientific diving operations. It also establishes a framework for reciprocity between AAUS organizational members that adhere to these minimum standards.

This standard was developed and written by AAUS by compiling the policies set forth in the diving manuals of several university, private, and governmental scientific diving programs. These programs share a common heritage with the scientific diving program at the Scripps Institution of Oceanography (SIO). Adherence to the SIO standards has proven both feasible and effective in protecting the health and safety of scientific divers since 1954.

In 1982, OSHA exempted scientific diving from commercial diving regulations (29CFR1910, Subpart T) under certain conditions that are outlined below. The final guidelines for the exemption became effective in 1985 (Federal Register, Vol. 50, No.6, p.1046). AAUS is recognized by OSHA as the scientific diving standard setting organization.

Additional standards that extend this document may be adopted by each organizational member, according to local procedure.

Scientific Diving Definition

Scientific diving is defined (29CFR1910.402) as diving performed solely as a necessary part of a scientific, research, or educational activity by employees whose sole purpose for diving is to perform scientific research tasks.

Scientific Diving Exemption

OSHA has granted an exemption for scientific diving from commercial diving regulations under the following guidelines (Appendix B to 29CFR1910 Subpart T):

a) The Diving Control Board consists of a majority of active scientific divers and has autonomous and absolute authority over the scientific diving program's operation.

b) The purpose of the project using scientific diving is the advancement of science; therefore, information and data resulting from the project are non-proprietary.

c) The tasks of a scientific diver are those of an observer and data gatherer. Construction and trouble-shooting tasks traditionally associated with commercial diving are not included within scientific diving.

d) Scientific divers, based on the nature of their activities, must use scientific expertise in studying the underwater environment and therefore, are scientists or scientists-in-training.

e) In addition, the scientific diving program shall contain at least the following elements (29CFR1910.401):

1. Diving safety manual which includes at a minimum: Procedures covering all diving operations specific to the program; including procedures for emergency care, recompression and evacuation, and the criteria for diver training and certification.

2. Diving control (safety) board, with the majority of its members being active scientific divers, which shall at a minimum have the authority to: approve and monitor diving projects, review and revise the diving safety manual, assure compliance with the manual, certify the depths to which a diver has been trained, take disciplinary action for unsafe practices, and assure adherence to the buddy system (a diver is accompanied by and is in continuous contact with another diver in the water) for scuba diving.

Review of Standards

As part of each organizational member's annual report, any recommendations for modifications of these standards shall be submitted to the AAUS for consideration.

1.20 Operational Control

Organizational Member Auspices Defined

For the purposes of these standards the auspices of the organizational member includes any scientific diving operation in which an organizational member is connected because of ownership of any equipment used, locations selected, or relationship with the individual(s) concerned. This includes all cases involving the operations of employees of the organizational member or employees of auxiliary organizations, where such employees are acting within the scope of their employment, and the operations of other persons who are engaged in scientific diving of the organizational member or are diving as members of an organization recognized by the AAUS organizational member.

It is the organizational member's responsibility to adhere to the AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs. The administration of the local diving program will reside with the organizational member's Diving Control Board (DCB).

The regulations herein shall be observed at all locations where scientific diving is conducted.

Organizational Member's Scientific Diving Standards and Safety Manual

Each organizational member shall develop and maintain a scientific diving safety manual that provides for the development and implementation of policies and procedures that will enable each organizational member to meet requirements of local environments and conditions as well as to comply with the AAUS scientific diving standards. The organizational member's scientific diving manual shall include, but not be limited to:

a) AAUS standards may be used as a set of minimal guidelines for the development of an organizational member's scientific diving safety manual. Volume 1, Sections 1.00 through 6.00 and the Appendices are required for all manuals. Volume 2, Sections 7.00 through 9.00 are required only when the organizational member conducts that diving activity. Organizational member specific sections are placed in Volume 2.

b) Emergency evacuation and medical treatment procedures.

c) Criteria for diver training and certification.

d) Standards written or adopted by reference for each diving mode utilized which include the following:

1. Safety procedures for the diving operation.
2. Responsibilities of the dive team members.
3. Equipment use and maintenance procedures.
4. Emergency procedures.

Diving Safety Officer

The Diving Safety Officer (DSO) serves as a member of the Diving Control Board (DCB). This person should have broad technical and scientific expertise in research related diving.

a) Qualifications

1. Shall be appointed by the responsible administrative officer or designee, with the advice and counsel of the Diving Control Board.
2. Shall be trained as a scientific diver.
3. Shall be a full member as defined by AAUS.
4. Shall be an active underwater instructor from an internationally recognized certifying agency.

b) Duties and Responsibilities

1. Shall be responsible, through the DCB, to the responsible administrative officer or designee, for the conduct of the scientific diving program of the membership organization. The routine operational authority for this program, including the conduct of training and certification, approval of dive plans, maintenance of diving records, and ensuring compliance with this standard and all relevant regulations of the membership organization, rests with the Diving Safety Officer.
2. May permit portions of this program to be carried out by a qualified delegate, although the Diving Safety Officer may not delegate responsibility for the safe conduct of the local diving program.
3. Shall be guided in the performance of the required duties by the advice of the DCB, but operational responsibility for the conduct of the local diving program will be retained by the Diving Safety Officer.
4. Shall suspend diving operations considered to be unsafe or unwise.

Diving Control Board

a) The Diving Control Board (DCB) shall consist of a majority of active scientific divers. Voting members shall include the Diving Safety Officer, the responsible administrative officer, or designee, and should include other representatives of the diving program such as qualified divers and members selected by procedures established by each organizational member. A chairperson and a secretary may be chosen from the membership of the board according to local procedure.

b) Has autonomous and absolute authority over the scientific diving program's operation.

c) Shall approve and monitor diving projects.

d) Shall review and revise the diving safety manual.

e) Shall assure compliance with the diving safety manual.

f) Shall certify the depths to which a diver has been trained.

g) Shall take disciplinary action for unsafe practices.

h) Shall assure adherence to the buddy system for scuba diving.

i) Shall act as the official representative of the membership organization in matters concerning the scientific diving program.

j) Shall act as a board of appeal to consider diver-related problems.

k) Shall recommend the issue, reissue, or the revocation of diving certifications.

l) Shall recommend changes in policy and amendments to AAUS and the membership organization's diving safety manual as the need arises.

m) Shall establish and/or approve training programs through which the applicants for certification can satisfy the requirements of the organizational member's diving safety manual.

n) Shall suspend diving programs that are considered to be unsafe or unwise.

o) Shall establish criteria for equipment selection and use.

p) Shall recommend new equipment or techniques.

q) Shall establish and/or approve facilities for the inspection and maintenance of diving and associated equipment.

r) Shall ensure that the organizational member's air station(s) meet air quality standards as described in Section 3.60.

s) Shall periodically review the Diving Safety Officer's performance and program.

t) Shall sit as a board of investigation to inquire into the nature and cause of diving accidents or violations of the organizational member's diving safety manual.

Instructional Personnel

a) Qualifications - All personnel involved in diving instruction under the auspices of the organizational member shall be qualified for the type of instruction being given.

b) Selection - Instructional personnel will be selected by the responsible administrative officer, or designee, who will solicit the advice of the DCB in conducting preliminary screening of applicants for instructional positions.

Lead Diver

For each dive, one individual shall be designated as the Lead Diver who shall be at the dive location during the diving operation. The Lead Diver shall be responsible for:

a) Coordination with other known activities in the vicinity that are likely to interfere with diving operations.

b) Ensuring all dive team members possess current certification and are qualified for the type of diving operation.

c) Planning dives in accordance with Section 2.20

d) Ensuring safety and emergency equipment is in working order and at the dive site.

e) Briefing dive team members on:

   1. Dive objectives.

   2. Unusual hazards or environmental conditions likely to affect the safety of the diving operation.

   3. Modifications to diving or emergency procedures necessitated by the specific diving operation.

   4. Suspending diving operations if in their opinion conditions are not safe.

   5. Reporting to the DSO and DCB any physical problems or adverse physiological effects including symptoms of pressure-related injuries.

Reciprocity and Visiting Scientific Diver

a) Two or more AAUS Organizational Members engaged jointly in diving activities, or engaged jointly in the use of diving resources, shall designate one of the participating Diving Control Boards to govern the joint dive project.

b) A Scientific Diver from one Organizational Member shall apply for permission to dive under the auspices of another Organizational Member by submitting to the Diving Safety Officer of the host Organizational Member a document containing all the information described in Appendix 6, signed by the Diving Safety Officer or Chairperson of the home Diving Control Board.

c) A visiting Scientific Diver may be asked to demonstrate their knowledge and skills for the planned dive.

d) If a host Organizational Member denies a visiting Scientific Diver permission to dive, the host Diving Control Board shall notify the visiting Scientific Diver and their Diving Control Board with an explanation of all reasons for the denial.

Waiver of Requirements

The organizational Diving Control Board may grant a waiver for specific requirements of training, examinations, depth certification, and minimum activity to maintain certification.

1.30 Consequence of Violation of Regulations by Scientific Divers

Failure to comply with the regulations of the organizational member's diving safety manual may be cause for the revocation or restriction of the diver's scientific diving certificate by action of the organizational member's Diving Control Board.

1.40 Consequences of Violation of Regulations by Organizational Members

Failure to comply with the regulations of this standard may be cause for the revocation or restriction of the organizational member's recognition by AAUS.

1.50 Record Maintenance

The Diving Safety Officer or designee shall maintain permanent records for each Scientific Diver certified. The file shall include evidence of certification level, log sheets, results of current physical examination, reports of disciplinary actions by the organizational member Diving Control Board, and other pertinent information deemed necessary.

Availability of Records:

a) Medical records shall be available to the attending physician of a diver or former diver when released in writing by the diver.

b) Records and documents required by this standard shall be retained by the organizational member for the following period:

1. Physician's written reports of medical examinations for dive team members - 5 years.
2. Diving safety manual - current document only.
3. Records of dive - 1 year, except 5 years where there has been an incident of pressure-related injury.
4. Pressure-related injury assessment - 5 years.
5. Equipment inspection and testing records - current entry or tag, or until equipment is withdrawn from service.

SECTION 2.00 DIVING REGULATIONS FOR SCUBA (OPEN CIRCUIT, COMPRESSED AIR)

2.10 Introduction

No person shall engage in scientific diving operations under the auspices of the member's organizational scientific diving program unless they hold a current certification issued pursuant to the provisions of this standard.

2.20 Pre-Dive Procedures

Dive Plans

Dives should be planned around the competency of the least experienced diver. Before conducting any diving operations under the auspices of the organizational member, the lead diver for a proposed operation must formulate a dive plan that should include the following:

a) Divers qualifications, and the type of certificate or certification held by each diver.

b) Emergency plan (Appendix 7) with the following information:

1. Name, telephone number, and relationship of person to be contacted for each diver in the event of an emergency.
2. Nearest operational decompression chamber.
3. Nearest accessible hospital.
4. Available means of transport.

c) Approximate number of proposed dives.

d) Location(s) of proposed dives.

e) Estimated depth(s) and bottom time(s) anticipated.

f) Decompression status and repetitive dive plans, if required.

g) Proposed work, equipment, and boats to be employed.

h) Any hazardous conditions anticipated.

Pre-dive Safety Checks

a) Diver's Responsibility:

1. Scientific divers shall conduct a functional check of their diving equipment in the presence of the diving buddy or tender.
2. It is the diver's responsibility and duty to refuse to dive if, in their judgment, conditions are unfavorable, or if they would be violating the precepts of their training, of this standard, or the organizational member's diving safety manual.
3. No dive team member shall be required to be exposed to hyperbaric conditions against their will, except when necessary to prevent or treat a pressure-related injury.
4. No dive team member shall be permitted to dive for the duration of any known condition, which is likely to adversely affect the safety and health of the diver or other dive members.

b) Equipment Evaluations

1. Divers shall ensure that their equipment is in proper working order and that the equipment is suitable for the type of diving operation.

2. Each diver shall have the capability of achieving and maintaining positive buoyancy.

c) Site Evaluation - Environmental conditions at the site will be evaluated.

2.30 Diving Procedures

Solo Diving Prohibition

All diving activities shall assure adherence to the buddy system for scuba diving. This buddy system is based upon mutual assistance, especially in the case of an emergency.

Refusal to Dive

a) The decision to dive is that of the diver. A diver may refuse to dive, without fear of penalty, whenever they feel it is unsafe for them to make the dive.

b) Safety - The ultimate responsibility for safety rests with the individual diver. It is the diver's responsibility and duty to refuse to dive if, in their judgment, conditions are unsafe or unfavorable, or if they would be violating the precepts of their training or the regulations in this standard.

Termination of the Dive

a) It is the responsibility of the diver to terminate the dive, without fear of penalty, whenever they feel it is unsafe to continue the dive, unless it compromises the safety of another diver already in the water.

b) The dive shall be terminated while there is still sufficient cylinder pressure to permit the diver to safely reach the surface, including decompression time, or to safely reach an additional air source at the decompression station.

Emergencies and Deviations from Regulations

Any diver may deviate from the requirements of this standard to the extent necessary to prevent or minimize a situation that is likely to cause death, serious physical harm, or major environmental damage. A written report of such actions must be submitted to the Diving Control Board explaining the circumstances and justifications.

2.40 Post-Dive Procedures

Post-Dive Safety Checks

a) After the completion of a dive, each diver shall report any physical problems, symptoms of decompression sickness, or equipment malfunctions.

b) When diving outside the no-decompression limits, the divers should remain awake for at least 1 hour after diving, and in the company of a dive team member who is prepared to transport them to a decompression chamber if necessary.

2.50 Emergency Procedures

Each organizational member will develop emergency procedures which follow the standards of care of the community and must include procedures for emergency care, recompression and evacuation for each dive location (Appendix 7).

2.60 Flying After Diving or Ascending to Altitude (Over 1000 feet)

Following a Single No-Decompression Dive: Divers should have a minimum preflight surface interval of 12 hours.

Following Multiple Dives per Day or Multiple Days of Diving: Divers should have a minimum preflight surface interval of 18 hours.

Following Dives Requiring Decompression Stops: Divers should have a minimum preflight surface interval of 24 hours.

Before ascending to Altitude above (1000 feet) by Land Transport: Divers should follow the appropriate guideline for preflight surface intervals unless the decompression procedure used has accounted for the increase in elevation.

2.70 Record Keeping Requirements

Personal Diving Log

Each certified scientific diver shall log every dive made under the auspices of the organizational member's program, and is encouraged to log all other dives. Standard forms will be provided by each membership organization. Log sheets shall be submitted to the Diving Safety Officer to be placed in the diver's permanent file. Details of the submission procedures are left to the discretion of the Diving Safety Officer. The diving log shall be in a form specified by the organization and shall include at least the following:

a) Name of diver, buddy, and Lead Diver.

b) Date, time, and location.

c) Diving modes used.

d) General nature of diving activities.

e) Approximate surface and underwater conditions.

f) Maximum depths, bottom time, and surface interval time.

g) Diving tables or computers used.

h) Detailed report of any near or actual incidents.

Required Incident Reporting

All diving incidents requiring recompression treatment, or resulting in moderate or serious injury, or death shall be reported to the Organizational Member's Diving Control Board and the AAUS. The organizational member's regular procedures for incident reporting, including those required by the AAUS, shall be followed. The report will specify the circumstances of the incident and the extent of any injuries or illnesses.

Additional information must meet the following reporting requirements:

a) Organizational member shall record and report occupational injuries and illnesses in accordance with requirements of the appropriate Labor Code section.

b) If pressure-related injuries are suspected, or if symptoms are evident, the following additional information shall be recorded and retained by the organizational member, with the record of the dive, for a period of 5 years:

1. Complete AAUS Incident Report at http://www.aaus.org.

2. Written descriptive report to include:

   - Name, address, phone numbers of the principal parties involved.
   - Summary of experience of divers involved.
   - Location, description of dive site, and description of conditions that led up to incident.
   - Description of symptoms, including depth and time of onset.
   - Description and results of treatment.
   - Disposition of case.
   - Recommendations to avoid repetition of incident.

c) Organizational member shall investigate and document any incident of pressure-related injury and prepare a report that is to be forwarded to AAUS during the annual reporting cycle. This report must first be reviewed and released by the organizational member's Diving Control Board.

SECTION 3.00 DIVING EQUIPMENT

3.10 General Policy

All equipment shall meet standards as determined by the Diving Safety Officer and the Diving Control Board. Equipment that is subjected to extreme usage under adverse conditions should require more frequent testing and maintenance.

All equipment shall be regularly examined by the person using them.

3.20 Equipment

Regulators

a) Only those makes and models specifically approved by the Diving Safety Officer and the Diving Control Board shall be used.

b) Scuba regulators shall be inspected and tested prior to first use and every 12 months thereafter.

c) Regulators will consist of a primary second stage and an alternate air source (such as an octopus second stage or redundant air supply).

Breathing Masks and Helmets

Breathing masks and helmets shall have:

a) A non-return valve at the attachment point between helmet or mask and hose, which shall close readily and positively.

b) An exhaust valve.

c) A minimum ventilation rate capable of maintaining the diver at the depth to which they are diving.

Scuba Cylinders

a) Scuba cylinders shall be designed, constructed, and maintained in accordance with the applicable provisions of the Unfired Pressure Vessel Safety Orders.

b) Scuba cylinders must be hydrostatically tested in accordance with DOT standards.

c) Scuba cylinders must have an internal and external inspection at intervals not to exceed 12 months.

d) Scuba cylinder valves shall be functionally tested at intervals not to exceed 12 months.

Backpacks

Backpacks without integrated flotation devices and weight systems shall have a quick release device designed to permit jettisoning with a single motion from either hand.

Gauges

Gauges shall be inspected and tested before first use and every 12 months thereafter.

Flotation Devices

a) Each diver shall have the capability of achieving and maintaining positive buoyancy.

b) Personal flotation systems, buoyancy compensators, dry suits, or other variable volume buoyancy compensation devices shall be equipped with an exhaust valve.

c) These devices shall be functionally inspected and tested at intervals not to exceed 12 months.

Timing Devices, Depth, and Pressure Gauges

Both members of the buddy team must have an underwater timing device, an approved depth indicator, and a submersible pressure gauge.

Determination of Decompression Status: Dive Tables, Dive Computers

a) A set of diving tables, approved by the Diving Control Board, must be available at the dive location.

b) Dive computers may be utilized in place of diving tables, and must be approved by the Diving Control Board. AAUS recommendations on dive computers are located in appendix 8

3.30 Auxiliary Equipment

Hand held underwater power tools. Electrical tools and equipment used underwater shall be specifically approved for this purpose. Electrical tools and equipment supplied with power from the surface shall be de-energized before being placed into or retrieved from the water. Hand held power tools shall not be supplied with power from the dive location until requested by the diver.

3.40 Support Equipment

First aid supplies

A first aid kit and emergency oxygen shall be available.

Diver's Flag

A diver's flag shall be displayed prominently whenever diving is conducted under circumstances where required or where water traffic is probable.

Compressor Systems - Organizational Member Controlled

The following will be considered in design and location of compressor systems:

a) Low-pressure compressors used to supply air to the diver if equipped with a volume tank shall have a check valve on the inlet side, a relief valve, and a drain valve.

b) Compressed air systems over 500 psig shall have slow-opening shut-off valves.

c) All air compressor intakes shall be located away from areas containing exhaust or other contaminants.

3.50 Equipment Maintenance

Record Keeping

Each equipment modification, repair, test, calibration, or maintenance service shall be logged, including the date and nature of work performed, serial number of the item, and the name of the person performing the work for the following equipment:

a) Regulators
b) Submersible pressure gauges
c) Depth gauges
d) Scuba cylinders
e) Cylinder valves
f) Diving helmets
g) Submersible breathing masks
h) Compressors
i) Gas control panels
j) Air storage cylinders
k) Air filtration systems
l) Analytical instruments
m) Buoyancy control devices
n) Dry suits

Compressor Operation and Air Test Records

a) Gas analyses and air tests shall be performed on each organizational member-controlled breathing air compressor at regular intervals of no more than 100 hours of operation or 6 months, whichever occurs first. The results of these tests shall be entered in a formal log and be maintained.

b) A log shall be maintained showing operation, repair, overhaul, filter maintenance, and temperature adjustment for each compressor.

3.60 Air Quality Standards

Breathing air for scuba shall meet the following specifications as set forth by the Compressed Gas Association (CGA Pamphlet G-7.1).

CGA Grade E	
Component	**Maximum**
Oxygen	20 - 22%/v
Carbon Monoxide	10 PPM/v
Carbon Dioxide	1000 PPM/v
Condensed Hydrocarbons	5 mg/m3
Total Hydrocarbons as Methane	25 PPM/v
Water Vapor ppm	(2)
Objectionable Odors	None

For breathing air used in conjunction with self-contained breathing apparatus in extreme cold where moisture can condense and freeze, causing the breathing apparatus to malfunction, a dew point not to exceed -50°F (63 pm v/v) or 10 degrees lower than the coldest temperature expected in the area is required.

SECTION 4.00 ENTRY-LEVEL TRAINING REQUIREMENTS

This section describes training for the non-diver applicant, previously not certified for diving, and equivalency for the certified diver.

4.10 Evaluation

Medical Examination

The applicant for training shall be certified by a licensed physician to be medically qualified for diving before proceeding with the training as designated in Section 4.20 (Section 6.00 and Appendices 1 through 4).

Swimming Evaluation

Applicant shall successfully perform the following tests, or equivalent, in the presence of the Diving Safety Officer, or an examiner approved by the Diving Safety Officer.

a) Swim underwater without swim aids for a distance of 25 yards without surfacing.

b) Swim 400 yards in less than 12 minutes without swim aids.

c) Tread water for 10 minutes, or 2 minutes without the use of hands, without swim aids.

d) Without the use of swim aids, transport another person of equal size a distance of 25 yards in the water.

4.20 Scuba Training

Practical Training

At the completion of training, the trainee must satisfy the Diving Safety Officer or the instructor of their ability to perform the following, as a minimum, in a pool or in sheltered water:

a) Enter water with full equipment.

b) Clear face mask.

c) Demonstrate air sharing, including both buddy breathing and the use of alternate air source, as both donor and recipient, with and without a face mask.

d) Demonstrate ability to alternate between snorkel and scuba while kicking.

e) Demonstrate understanding of underwater signs and signals.

f) Demonstrate simulated in-water mouth-to-mouth resuscitation.

g) Rescue and transport, as a diver, a passive simulated victim of an accident.

h) Demonstrate ability to remove and replace equipment while submerged.

i) Demonstrate watermanship ability, which is acceptable to the instructor.

Written Examination

Before completing training, the trainee must pass a written examination that demonstrates knowledge of at least the following:

a) Function, care, use, and maintenance of diving equipment.
b) Physics and physiology of diving.
c) Diving regulations and precautions.
d) Near-shore currents and waves.
e) Dangerous marine animals.
f) Emergency procedures, including buoyant ascent and ascent by air sharing.
g) Currently accepted decompression procedures.
h) Demonstrate the proper use of dive tables.
i) Underwater communications.
j) Aspects of freshwater and altitude diving.
k) Hazards of breath-hold diving and ascents.
l) Planning and supervision of diving operations.
m) Diving hazards.
n) Cause, symptoms, treatment, and prevention of the following: near drowning, air embolism, carbon dioxide excess, squeezes, oxygen poisoning, nitrogen narcosis, exhaustion and panic, respiratory fatigue, motion sickness, decompression sickness, hypothermia, and hypoxia/anoxia.

Open Water Evaluation

The trainee must satisfy an instructor, approved by the Diving Safety Officer, of their ability to perform at least the following in open water:

a) Surface dive to a depth of 10 feet in open water without scuba.
b) Demonstrate proficiency in air sharing as both donor and receiver.
c) Enter and leave open water or surf, or leave and board a diving vessel, while wearing scuba gear.
d) Kick on the surface 400 yards while wearing scuba gear, but not breathing from the scuba unit.
e) Demonstrate judgment adequate for safe diving.
f) Demonstrate, where appropriate, the ability to maneuver efficiently in the environment, at and below the surface.
g) Complete a simulated emergency swimming ascent.
h) Demonstrate clearing of mask and regulator while submerged.
i) Demonstrate ability to achieve and maintain neutral buoyancy while submerged.
j) Demonstrate techniques of self-rescue and buddy rescue.
k) Navigate underwater.
l) Plan and execute a dive.
m) Successfully complete 5 open water dives for a minimum total time of 3 hours, of which 1-1/2 hours cumulative bottom time must be on scuba. No more than 3 training dives shall be made in any 1day.

SECTION 5.00 SCIENTIFIC DIVER CERTIFICATION

5.10 Certification Types

Scientific Diver Certification

This is a permit to dive, usable only while it is current and for the purpose intended.

Temporary Diver Permit

This permit constitutes a waiver of the requirements of Section 5.00 and is issued only following a demonstration of the required proficiency in diving. It is valid only for a limited time, as determined by the Diving Safety Officer. This permit is not to be construed as a mechanism to circumvent existing standards set forth in this standard.

a) Requirements of this section may be waived by the Diving Safety Officer if the person in question has demonstrated proficiency in diving and can contribute measurably to a planned dive. A statement of the temporary diver's qualifications shall be submitted to the Diving Safety Officer as a part of the dive plan. Temporary permits shall be restricted to the planned diving operation and shall comply with all other policies, regulations, and standards of this standard, including medical requirements.

5.20 General Policy

AAUS requires that no person shall engage in scientific diving unless that person is authorized by an organizational member pursuant to the provisions of this standard. Only a person diving under the auspices of the organizational member that subscribes to the practices of AAUS is eligible for a scientific diver certification.

5.30 Requirements For Scientific Diver Certification

Submission of documents and participation in aptitude examinations does not automatically result in certification. The applicant must convince the Diving Safety Officer and members of the DCB that they are sufficiently skilled and proficient to be certified. This skill will be acknowledged by the signature of the Diving Safety Officer. Any applicant who does not possess the necessary judgment, under diving conditions, for the safety of the diver and their partner, may be denied organizational member scientific diving privileges. Minimum documentation and examinations required are as follows:

Prerequisites

a) Application - Application for certification shall be made to the Diving Safety Officer on the form prescribed by the organizational member.

b) Medical approval. Each applicant for diver certification shall submit a statement from a licensed physician, based on an approved medical examination, attesting to the applicant's fitness for diving (Section 6.00 and Appendices 1 through 4).

c) Scientific Diver-In-Training Permit - This permit signifies that a diver has completed and been certified as at least an open water diver through an internationally recognized certifying agency or scientific diving program, and has the knowledge skills and experience equivalent to that gained by successful completion of training as specified in Section 4.00.

Theoretical and Practical Training

The diver must complete theoretical aspects and practical training for a minimum cumulative time of 100 hours. Theoretical aspects shall include principles and activities appropriate to the intended area of scientific study.

a) Required Topics (include, but not limited to):

1. Diving Emergency Care Training
    - Cardiopulmonary Resuscitation (CPR)
    - Standard or Basic First Aid
    - Recognition of DCS and AGE
    - Accident Management
    - Field Neurological Exam
    - Oxygen Administration
2. Dive Rescue
3. Dive Physics
4. Dive Physiology
5. Dive Environments
6. Decompression Theory and its Application
7. AAUS Scientific Diving Regulations and History
    - Scientific Dive Planning
    - Coordination with other Agencies
    - Appropriate Governmental Regulations
8. Scientific Method
9. Data Gathering Techniques (Only Items specific to area of study are required)
    - Transect Sampling (Quadrating)
    - Transecting
    - Mapping
    - Coring
    - Photography
    - Tagging
    - Collecting
    - Animal Handling
    - Archaeology

- Common Biota
    - Organism Identification
    - Behavior
    - Ecology
- Site Selection, Location, and Re-location
- Specialized Equipment for data gathering
- HazMat Training
- HP Cylinders
- Chemical Hygiene, Laboratory Safety (Use Of Chemicals)

b) Suggested Topics (include, but not limited to):

1. Specific Dive Modes (methods of gas delivery)
    - Open Circuit
    - Hooka
    - Surface Supplied diving
2. Small Boat Operation
3. Rebreathers
    - Closed
    - Semi-closed
4. Specialized Breathing Gas
    - Nitrox
    - Mixed Gas
5. Specialized Environments and Conditions
    - Blue Water Diving,
    - Ice and Polar Diving (Cold Water Diving)
    - Zero Visibility Diving
    - Polluted Water Diving,
    - Saturation Diving
    - Decompression Diving
    - Overhead Environments
    - Aquarium Diving
    - Night Diving
    - Kelp Diving
    - Strong Current Diving (Live-boating)
    - Potential Entanglement
6. Specialized Diving Equipment
    - Full face mask
    - Dry Suit
    - Communications

c) Practical training must include a checkout dive, with evaluation of the skills listed in Section 4.20 (Open Water Evaluation), with the DSO or qualified delegate followed by at least 11 ocean or open water dives in a variety of dive sites and diving conditions, for a cumulative bottom time of 6 hours. Dives following the checkout dive must be supervised by a certified Scientific Diver with experience in the type of diving planned, with the knowledge and permission of the DSO.

d) Examinations

1. Written examination

- General exam required for scientific diver certification.
- Examination covering the suggested topics at the DSO's discretion.

2. Examination of equipment.

- Personal diving equipment
- Task specific equipment

5.40 Depth Certifications

Depth Certifications and Progression to Next Depth Level

A certified diver diving under the auspices of the organizational member may progress to the next depth level after successfully completing the required dives for the next level. Under these circumstances the diver may exceed their depth limit. Dives shall be planned and executed under close supervision of a diver certified to this depth, with the knowledge and permission of the DSO.

a) Certification to 30 Foot Depth - Initial permit level, approved upon the successful completion of training listed in Section 4.00 and 5.30.

b) Certification to 60 Foot Depth - A diver holding a 30 foot certificate may be certified to a depth of 60 feet after successfully completing, under supervision, 12 logged training dives to depths between 31 and 60 feet, for a minimum total time of 4 hours.

c) Certification to 100 Foot Depth - A diver holding a 60 foot certificate may be certified to a depth of 100 feet after successfully completing, 4 dives to depths between 61 and 100 feet. The diver shall also demonstrate proficiency in the use of the appropriate Dive Tables.

d) Certification to 130 Foot Depth - A diver holding a 100 foot certificate may be certified to a depth of 130 feet after successfully completing, 4 dives to depths between 100 and 130 feet. The diver shall also demonstrate proficiency in the use of the appropriate Dive Tables.

e) Certification to 150 Foot Depth - A diver holding a 130 foot certificate may be certified to a depth of 150 feet after successfully completing, 4 dives to depths between 130 and 150 feet. The diver must also demonstrate knowledge of the special problems of deep diving, and of special safety requirements.

f) Certification to 190 Foot Depth - A diver holding a 150 foot certificate may be certified to a depth of 190 feet after successfully completing, 4 dives to depths between 150 and 190 feet. The diver must also demonstrate knowledge of the special problems of deep diving, and of special safety requirements.

Diving on air is not permitted beyond a depth of 190 feet.

5.50 Continuation of Certificate

Minimum Activity to Maintain Certification

During any 12-month period, each certified scientific diver must log a minimum of 12 dives. At least one dive must be logged near the maximum depth of the diver's certification during each 6-month period. Divers certified to 150 feet or deeper may satisfy these requirements with dives to 130 feet or over. Failure to meet these requirements may be cause for revocation or restriction of certification.

Re-qualification of Depth Certificate

Once the initial certification requirements of Section 5.30 are met, divers whose depth certification has lapsed due to lack of activity may be re-qualified by procedures adopted by the organization's DCB.

Medical Examination

All certified scientific divers shall pass a medical examination at the intervals specified in Section 6.10. After each major illness or injury, as described in Section 6.10, a certified scientific diver shall receive clearance to return to diving from a physician before resuming diving activities.

Emergency Care Training.

The scientific diver must provide proof of training in the following:

- Adult CPR (must be current).
- Emergency oxygen administration (must be current)
- First aid for diving accidents (must be current)

5.60 Revocation of Certification

A diving certificate may be revoked or restricted for cause by the Diving Safety Officer or the DCB. Violations of regulations set forth in this standard, or other governmental subdivisions not in conflict with this standard, may be considered cause. Diving Safety Officer shall inform the diver in writing of the reason(s) for revocation. The diver will be given the opportunity to present their case in writing for reconsideration and/or re-certification. All such written statements and requests, as identified in this section, are formal documents, which will become part of the diver's file.

5.70 Recertification

If a diver's certificate expires or is revoked, they may be re-certified after complying with such conditions as the Diving Safety Officer or the DCB may impose. The diver shall be given an opportunity to present their case to the DCB before conditions for re-certification are stipulated.

SECTION 6.00 MEDICAL STANDARDS

6.10 Medical Requirements

General

g) The organizational member shall determine that divers have passed a current diving physical examination and have been declared by the examining physician to be fit to engage in diving activities as may be limited or restricted in the medical evaluation report.

h) All medical evaluations required by this standard shall be performed by, or under the direction of, a licensed physician of the applicant-diver's choice, preferably one trained in diving/undersea medicine.

i) The diver should be free of any chronic disabling disease and any conditions contained in the list of conditions for which restrictions from diving are generally recommended. (Appendix 1)

Frequency of Medical Evaluations

Medical evaluation shall be completed:

j) Before a diver may begin diving, unless an equivalent initial medical evaluation has been given within the preceding 5 years (3 years if over the age of 40, 2 years if over the age of 60), the member organization has obtained the results of that examination, and those results have been reviewed and found satisfactory by the member organization.

k) Thereafter, at 5 year intervals up to age 40, every 3 years after the age of 40, and every 2 years after the age of 60.

l) Clearance to return to diving must be obtained from a physician following any major injury or illness, or any condition requiring hospital care or chronic medication. If the injury or illness is pressure related, then the clearance to return to diving must come from a physician trained in diving medicine.

Information Provided Examining Physician

The organizational member shall provide a copy of the medical evaluation requirements of this standard to the examining physician. (Appendices 1, 2, and 3).

Content of Medical Evaluations

Medical examinations conducted initially and at the intervals specified in Section 6.10 shall consist of the following:

m) Applicant agreement for release of medical information to the Diving Safety Officer and the DCB (Appendix 2).

n) Medical history (Appendix 3).

o) Diving physical examination (Required tests listed below and in Appendix 2).

Conditions Which May Disqualify Candidates From Diving (Adapted from Bove, 1998)

p) Abnormalities of the tympanic membrane, such as perforation, presence of a monomeric membrane, or inability to auto inflate the middle ears.
q) Hearing loss; Vertigo including Meniere's Disease.
r) Stapedectomy or middle ear reconstructive surgery.
s) Recent ocular surgery.
t) Psychiatric disorders including claustrophobia, suicidal ideation, psychosis, anxiety states, depression.
u) Substance abuse, including alcohol.
v) Episodic loss of consciousness.
w) History of seizure.
x) History of stroke or a fixed neurological deficit.
y) Recurring neurologic disorders, including transient ischemic attacks.
z) History of intracranial aneurysm, other vascular malformation or intracranial hemorrhage.
aa) History of neurological decompression illness with residual deficit.
bb) Head injury.
cc) Hematologic disorders including coagulopathies.
dd) Risk factors or evidence of coronary artery disease.
ee) Atrial septal defects.
ff) Significant valvular heart disease - isolated mitral valve prolapse is not disqualifying.
gg) Significant cardiac rhythm or conduction abnormalities.
hh) Implanted cardiac pacemakers and cardiac defibrillators (ICD).
ii) Inadequate exercise tolerance.
jj) Hypertension.
kk) History of pneumothorax.
ll) Asthma.
mm) Chronic pulmonary disease, including radiographic evidence of pulmonary blebs, bullae or cysts.
nn) Diabetes mellitus.
oo) Pregnancy.

Laboratory Requirements for Diving Medical Evaluation and Intervals.

pp) Initial examination under age 40:

* Medical History
* Complete Physical Exam, emphasis on neurological and otological components
* Urinalysis
* Any further tests deemed necessary by the physician.

qq) Periodic re-examination under age 40 (every 5 years):

* Medical History
* Complete Physical Exam, emphasis on neurological and otological components
* Urinalysis
* Any further tests deemed necessary by the physician

rr) First exam over age 40:

* Medical History

* Complete Physical Exam, emphasis on neurological and otological components
* Detailed assessment of coronary artery disease risk factors using Multiple-Risk-Factor Assessment[1,2] (age, family history, lipid profile, blood pressure, diabetic screening, smoking history). Further cardiac screening may be indicated based on risk factor assessment.
* Resting EKG
* Chest X-ray
* Urinalysis
* Any further tests deemed necessary by the physician

ss) Periodic re-examination over age 40 (every 3 years); over age 60 (every 2 years):

* Medical History
* Complete Physical Exam, emphasis on neurological and otological components
* Detailed assessment of coronary artery disease risk factors using Multiple-Risk-Factor Assessment[1] (age, family history, lipid profile, blood pressure, diabetic screening, smoking history). Further cardiac screening may be indicated based on risk factor assessment.
* Resting EKG
* Urinalysis
* Any further tests deemed necessary by the physician

tt) Physician's Written Report

1. After any medical examination relating to the individual's fitness to dive, the organizational member shall obtain a written report prepared by the examining physician that shall contain the examining physician's opinion of the individual's fitness to dive, including any recommended restrictions or limitations. This report will be reviewed by the DCB.
2. The organizational member shall make a copy of the physician's written report available to the individual.

[1] Grundy, R.J. et. al. 1999. Assessment of Cardiovascular Risk by Use of Multiple-Risk-Factor Assessment Equations. AHA/ACC Scientific Statement. http://www.acc.org/clinical/consensus/risk/risk1999.pdf
[2] Bove, A.A. 2011. The cardiovascular system and diving risk. *Undersea and Hyperbaric Medicine* 38(4): 261-269.

Volume 2

Sections 7.00 through 12.00
Required Only When Conducting Described Diving Activities
and
Organizational Member Specific Sections

SECTION 7.00 NITROX DIVING GUIDELINES

The following guidelines address the use of nitrox by scientific divers under the auspices of an AAUS Organizational Member. Nitrox is defined for these guidelines as breathing mixtures composed predominately of nitrogen and oxygen, most commonly produced by the addition of oxygen or the removal of nitrogen from air.

7.10 Prerequisites

Eligibility

Only a certified Scientific Diver or Scientific Diver In Training (Sections 4.00 and 5.00) diving under the auspices of a member organization is eligible for authorization to use nitrox. After completion, review and acceptance of application materials, training and qualification, an applicant will be authorized to use nitrox within their depth authorization, as specified in Section 5.40.

Application and Documentation

Application and documentation for authorization to use nitrox should be made on forms specified by the Diving Control Board.

7.20 Requirements for Authorization to Use Nitrox

Submission of documents and participation in aptitude examinations does not automatically result in authorization to use nitrox. The applicant must convince the DSO and members of the DCB that they are sufficiently skilled and proficient. The signature of the DSO on the authorization form will acknowledge authorization. After completion of training and evaluation, authorization to use nitrox may be denied to any diver who does not demonstrate to the satisfaction of the DSO or DCB the appropriate judgment or proficiency to ensure the safety of the diver and dive buddy.

Prior to authorization to use nitrox, the following minimum requirements should be met:

Training

The diver must complete additional theoretical and practical training beyond the Scientific Diver In Training air certification level, to the satisfaction of the member organizations DSO and DCB (Section 7.30).

Examinations

Each diver should demonstrate proficiency in skills and theory in written, oral, and practical examinations covering:

a) Written examinations covering the information presented in the classroom training session(s) (i.e., gas theory, oxygen toxicity, partial pressure determination, etc.);

b) Practical examinations covering the information presented in the practical training session(s) (i.e., gas analysis, documentation procedures, etc.);

c) Openwater checkout dives, to appropriate depths, to demonstrate the application of theoretical and practical skills learned.

Minimum Activity to Maintain Authorization

The diver should log at least one nitrox dive per year. Failure to meet the minimum activity level may be cause for restriction or revocation of nitrox authorization.

7.30 Nitrox Training Guidelines

Training in these guidelines should be in addition to training for Diver-In-Training authorization (Section 4.00). It may be included as part of training to satisfy the Scientific Diver training requirements (Section 5.30).

Classroom Instruction

d) Topics should include, but are not limited to: review of previous training; physical gas laws pertaining to nitrox; partial pressure calculations and limits; equivalent air depth (EAD) concept and calculations; oxygen physiology and oxygen toxicity; calculation of oxygen exposure and maximum safe operating depth (MOD); determination of decompression schedules (both by EAD method using approved air dive tables, and using approved nitrox dive tables); dive planning and emergency procedures; mixing procedures and calculations; gas analysis; personnel requirements; equipment marking and maintenance requirements; dive station requirements.

e) DCB may choose to limit standard nitrox diver training to procedures applicable to diving, and subsequently reserve training such as nitrox production methods, oxygen cleaning, and dive station topics to divers requiring specialized authorization in these areas.

Practical Training

The practical training portion will consist of a review of skills as stated for scuba (Section 4.00), with additional training as follows:

a) Oxygen analysis of nitrox mixtures.

b) Determination of MOD, oxygen partial pressure exposure, and oxygen toxicity time limits, for various nitrox mixtures at various depths.

c) Determination of nitrogen-based dive limits status by EAD method using air dive tables, and/or using nitrox dive tables, as approved by the DCB.

d) Nitrox dive computer use may be included, as approved by the DCB.

Written Examination (based on classroom instruction and practical training)

Before authorization, the trainee should successfully pass a written examination demonstrating knowledge of at least the following:

a) Function, care, use, and maintenance of equipment cleaned for nitrox use.

b) Physical and physiological considerations of nitrox diving (ex.: O_2 and CO_2 toxicity).

c) Diving regulations and procedures as related to nitrox diving, either scuba or surface-supplied (depending on intended mode).

d) Given the proper information, calculation of:

1. Equivalent air depth (EAD) for a given fO_2 and actual depth;
2. pO_2 exposure for a given fO_2 and depth;
3. Optimal nitrox mixture for a given pO_2 exposure limit and planned depth;
4. Maximum operational depth (MOD) for a given mix and pO_2 exposure limit;
5. For nitrox production purposes, percentages/psi of oxygen present in a given mixture, and psi of each gas required to produce a fO_2 by partial pressure mixing.

e) Dive table and dive computer selection and usage;

f) Nitrox production methods and considerations.

g) Oxygen analysis.

h) Nitrox operational guidelines (Section 7.40), dive planning, and dive station components.

Openwater Dives

A minimum of two supervised openwater dives using nitrox is required for authorization. The mode used in the dives should correspond to the intended application (i.e., scuba or surface-supplied). If the MOD for the mix being used can be exceeded at the training location, direct, in-water supervision is required.

Surface-Supplied Training

All training as applied to surface-supplied diving (practical, classroom, and openwater) will follow the member organization's surface-supplied diving standards, including additions listed in Section 11.60.

7.40 Scientific Nitrox Diving Regulations

Dive Personnel Requirements

a) Nitrox Diver In Training - A Diver In Training, who has completed the requirements of Section 4.00 and the training and authorization sections of these guidelines, may be authorized by the DSO to use nitrox under the direct supervision a Scientific Diver who also holds nitrox authorization. Dive depths should be restricted to those specified in the diver's authorization.

b) Scientific Diver - A Scientific Diver who has completed the requirements of Section 5.00 and the training and authorization sections of these guidelines, may be authorized by the DSO to use nitrox. Depth authorization to use nitrox should be the same as those specified in the diver's authorization, as described in Section. 5.40.

c) Lead Diver - On any dive during which nitrox will be used by any team member, the Lead Diver should be authorized to use nitrox, and hold appropriate authorizations required for the dive, as specified in AAUS Standards. Lead Diver authorization for nitrox dives by the DSO and/or DCB should occur as part of the dive plan approval process.

In addition to responsibilities listed in Section 1.20, the Lead Diver should:

1. As part of the dive planning process, verify that all divers using nitrox on a dive are properly qualified and authorized;

2. As part of the pre-dive procedures, confirm with each diver the nitrox mixture the diver is using, and establish dive team maximum depth and time limits, according to the shortest time limit or shallowest depth limit among the team members.

3. The Lead Diver should also reduce the maximum allowable pO_2 exposure limit for the dive team if on-site conditions so indicate (see Sec. 7.42.).

Dive Parameters

a) Oxygen Exposure Limits

1. The inspired oxygen partial pressure experienced at depth should not exceed 1.6 ATA. All dives performed using nitrox breathing mixtures should comply with the current *NOAA Diving Manual* "Oxygen Partial Pressure Limits for 'Normal' Exposures"

2. The maximum allowable exposure limit should be reduced in cases where cold or strenuous dive conditions, or extended exposure times are expected. The DCB should consider this in the review of any dive plan application, which proposes to use nitrox. The Lead Diver should also review on-site conditions and reduce the allowable pO_2 exposure limits if conditions indicate.

3. If using the equivalent air depth (EAD) method the maximum depth of a dive should be based on the oxygen partial pressure for the specific nitrox breathing mix to be used.

b) Bottom Time Limits

1. Maximum bottom time should be based on the depth of the dive and the nitrox mixture being used.

2. Bottom time for a single dive should not exceed the NOAA maximum allowable "Single Exposure Limit" for a given oxygen partial pressure, as listed in the current NOAA Diving Manual.

c) Dive Tables and Gases

1. A set of DCB approved nitrox dive tables should be available at the dive site.

2. When using the equivalent air depth (EAD) method, dives should be conducted using air dive tables approved by the DCB.

3. If nitrox is used to increase the safety margin of air-based dive tables, the MOD and oxygen exposure and time limits for the nitrox mixture being dived should not be exceeded

4. Breathing mixtures used while performing in-water decompression, or for bail-out purposes, should contain the same or greater oxygen content as that being used during the dive, within the confines of depth limitations and oxygen partial pressure limits set forth in Section 7.40 Dive Parameters.

d) Nitrox Dive Computers

1. Dive computers may be used to compute decompression status during nitrox dives. Manufacturers' guidelines and operations instructions should be followed.

2. Use of Nitrox dive computers should comply with dive computer guidelines included in the AAUS Standards.

3. Nitrox dive computer users should demonstrate a clear understanding of the display, operations, and manipulation of the unit being used for nitrox diving prior to using the computer, to the satisfaction of the DSO or designee.

4. If nitrox is used to increase the safety margin of an air-based dive computer, the MOD and oxygen exposure and time limits for the nitrox mixture being dived shall not be exceeded.

5. Dive computers capable of pO_2 limit and fO_2 adjustment should be checked by the diver prior to the start each dive to assure compatibility with the mix being used.

e) Repetitive Diving

1. Repetitive dives using nitrox mixtures should be performed in compliance with procedures required of the specific dive tables used.

2. Residual nitrogen time should be based on the EAD for the specific nitrox mixture to be used on the repetitive dive, and not that of the previous dive.

3. The total cumulative exposure (bottom time) to a partial pressure of oxygen in a given 24 hour period should not exceed the current *NOAA Diving Manual* 24-hour Oxygen Partial Pressure Limits for "Normal" Exposures.

4. When repetitive dives expose divers to different oxygen partial pressures from dive to dive, divers should account for accumulated oxygen exposure from previous dives when determining acceptable exposures for repetitive dives. Both acute (CNS) and chronic (pulmonary) oxygen toxicity concerns should be addressed.

f) Oxygen Parameters

1. Authorized Mixtures - Mixtures meeting the criteria outlined in Section 7.40 may be used for nitrox diving operations, upon approval of the DCB.

2. Purity - Oxygen used for mixing nitrox-breathing gas should meet the purity levels for "Medical Grade" (U.S.P.) or "Aviator Grade" standards.

   In addition to the AAUS Air Purity Guidelines (Section 3.60), the following standard should be met for breathing air that is either:

   a. Placed in contact with oxygen concentrations greater than 40%.

   b. Used in nitrox production by the partial pressure mixing method with gas mixtures containing greater than 40% oxygen as the enriching agent.

Air Purity: CGA Grade E (Section 3.60)	
Condensed Hydrocarbons	$5 mg/m^3$
Hydrocarbon Contaminants	No greater than $0.1 mg/m^3$

g) Gas Mixing and Analysis for Organizational Members

1. Personnel Requirements

   a. Individuals responsible for producing and/or analyzing nitrox mixtures should be knowledgeable and experienced in all aspects of the technique.

   b. Only those individuals approved by the DSO and/or DCB should be responsible for mixing and/or analyzing nitrox mixtures.

2. Production Methods - It is the responsibility of the DCB to approve the specific nitrox production method used.

3. Analysis Verification by User

   a. It is the responsibility of each diver to analyze prior to the dive the oxygen content of his/her scuba cylinder and acknowledge in writing the following information for each cylinder: fO_2, MOD, cylinder pressure, date of analysis, and user's name.

   b. Individual dive log reporting forms should report fO_2 of nitrox used, if different than 21%.

7.50 Nitrox Diving Equipment

All of the designated equipment and stated requirements regarding scuba equipment required in the AAUS Standards should apply to nitrox scuba operations. Additional minimal equipment necessary for nitrox diving operations includes:

- Labeled SCUBA Cylinders
- Oxygen Analyzers

Oxygen Cleaning and Maintenance Requirements

a) Requirement for Oxygen Service

1. All equipment, which during the dive or cylinder filling process is exposed to concentrations greater than 40% oxygen at pressures above 150 psi, should be cleaned and maintained for oxygen service.

2. Equipment used with oxygen or mixtures containing over 40% by volume oxygen shall be designed and maintained for oxygen service. Oxygen systems over 125 psig shall have slow-opening shut-off valves. This should include the following equipment: scuba cylinders, cylinder valves, scuba and other regulators, cylinder pressure gauges, hoses, diver support equipment, compressors, and fill station components and plumbing.

b) Scuba Cylinder Identification Marking

Scuba cylinders to be used with nitrox mixtures should have the following identification documentation affixed to the cylinder.

1. Cylinders should be marked “NITROX”, or “EANx”, or “Enriched Air”.
2. Nitrox identification color-coding should include a 4-inch wide green band around the cylinder, starting immediately below the shoulder curvature. If the cylinder is not yellow, the green band should be bordered above and below by a 1-inch yellow band.
3. The alternate marking of a yellow cylinder by painting the cylinder crown green and printing the word “NITROX” parallel to the length of the cylinder in green print is acceptable.
4. Other markings, which identify the cylinder as containing gas mixes other than Air, may be used as the approval of the DCB.
5. A contents label should be affixed, to include the current fO_2, date of analysis, and MOD.
6. The cylinder should be labeled to indicate whether the cylinder is prepared for oxygen or nitrox mixtures containing greater than 40% oxygen.

c) Regulators - Regulators to be used with nitrox mixtures containing greater than 40% oxygen should be cleaned and maintained for oxygen service, and marked in an identifying manner.

d) Other Support Equipment

1. An oxygen analyzer is required which is capable of determining the oxygen content in the scuba cylinder. Two analyzers are recommended to reduce the likelihood of errors due to a faulty analyzer. The analyzer should be capable of reading a scale of 0 to 100% oxygen, within 1% accuracy.
2. All diver and support equipment should be suitable for the fO_2 being used.

e) Compressor system

1. Compressor/filtration system must produce oil-free air.
2. An oil-lubricated compressor placed in service for a nitrox system should be checked for oil and hydrocarbon contamination at least quarterly.

f) Fill Station Components - All components of a nitrox fill station that will contact nitrox mixtures containing greater than 40% oxygen should be cleaned and maintained for oxygen service. This includes cylinders, whips, gauges, valves, and connecting lines.

SECTION 8.00 AQUARIUM DIVING OPERATIONS

8.10 General Policy

Section 8.00 applies to scientific aquarium divers only.

Definition - A scientific aquarium diver is a scientific diver who is diving solely within an aquarium. An aquarium is a shallow, confined body of water, which is operated by or under the control of an institution and is used for the purposes of specimen exhibit, education, husbandry, or research.

It is recognized that within scientific aquarium diving there are environments and equipment that fall outside the scope of those addressed in this standard. In those circumstances it is the responsibility of the organizational member's Dive Control Board to establish the requirements and protocol under which diving will be safely conducted.

Note: All of the standards set forth in other sections of this standard shall apply, except as otherwise provided in this section.

8.20 The Buddy System In Scientific Aquarium Diving

All scuba diving activities in the confined environment of an aquarium shall be conducted in accordance with the buddy system, whereby both divers, or a diver and a tender as provided below, are always in visual contact with one another, can always communicate with one another, and can always render prompt and effective assistance either in response to an emergency or to prevent an emergency.

A diver and tender comprise a buddy team in the confined environment of an aquarium only when the maximum depth does not exceed 30 feet, and there are no overhead obstructions or entanglement hazards for the diver, and the tender is equipped, ready and able to conduct or direct a prompt and effective in-water retrieval of the diver at all times during the dive.

8.30 Diving Equipment

Section 3.20 is modified to read as follows:

In an aquarium of a known maximum obtainable depth:

1. A depth indicator is not required, except that a repetitive diver shall use the same computer used on any prior dive.
2. Only one buddy must be equipped with a timing device.
3. The maximum obtainable depth of the aquarium shall be used as the diving depth.

8.40 Scientific Aquarium Diver Certification

A Scientific Aquarium Diver is a certification enabling the qualified diver to participate in scientific diving in accordance with Section 8.00 as provided below.

All of the standards set forth in sections 4.0 and 5.0 of this standard shall apply, except that Section 5.30 of this standard is modified to read as follows:

Practical training shall include at least 12 supervised aquarium dives for a cumulative bottom time of 6 hours. No more than 3 of these dives shall be made in 1 day.

8.50 Scientific Aquarium Diving Using Other Diving Technology

Surface Supplied Scientific Aquarium Diving

Definition: For purposes of scientific aquarium diving, surface supplied diving is described as a mode of diving using open circuit, surface supplied compressed gas which is provided to the diver at the dive location and may or may not include voice communication with the surface tender.

a) Divers using the surface supplied mode shall be equipped with a diver-carried independent reserve breathing gas supply.

   Scientific aquarium divers using conventional scuba masks, full-face masks, or non-lockdown type helmets are exempt from this standard provided:

   1. There are no overhead obstructions or entanglements.
   2. The diver is proficient in performing a Controlled Emergency Swimming Ascent from at least as deep as the maximum depth of the aquarium.
   3. The diver is proficient in performing out of air emergency drills, including ascent and mask/helmet removal.
   4. Each surface supplied diver shall be hose-tended by a separate dive team member while in the water. Scientific aquarium divers are exempt from this standard, provided the tender is monitoring only one air source, there is mutual assistance between divers and there are no overhead obstructions or entanglements.

b) Divers using the surface supplied mode shall maintain communication with the surface tender. The surface supplied breathing gas supply (volume and intermediate pressure) shall be sufficient to support all surface supplied divers in the water for the duration of the planned dive.

c) During surface supplied diving operations when only one diver is in the water, there must be a standby diver in attendance at the dive location. Scientific aquarium divers are exempt from this standard, provided the tender is equipped, ready and able to conduct a prompt and effective in-water retrieval of the diver at all times during the dive."

d) Surface supplied equipment must be configured to allow retrieval of the diver by the surface tender without risk of interrupting air supply to the diver.

e) All surface supplied applications used for scientific aquarium diving shall have a non-return valve at the attachment point between helmet or mask hose, which shall close readily and positively.

SECTION 9.00 STAGED DECOMPRESSION DIVING

Decompression diving shall be defined as any diving during which the diver cannot perform a direct return to the surface without performing a mandatory decompression stop to allow the release of inert gas from the diver's body.

The following procedures shall be observed when conducting dives requiring planned decompression stops.

9.10 Minimum Experience and Training Requirements

a) Prerequisites:

1. Scientific Diver qualification according to Section 5.00.
2. Minimum of 100 logged dives.
3. Demonstration of the ability to safely plan and conduct dives deeper than 100 feet.
4. Nitrox certification/authorization according to AAUS Section 7.00 recommended.

b) Training shall be appropriate for the conditions in which dive operations are to be conducted.

c) Minimum Training shall include the following:

1. A minimum of 6 hours of classroom training to ensure theoretical knowledge to include: physics and physiology of decompression; decompression planning and procedures; gas management; equipment configurations; decompression method, emergency procedures.
2. It is recommended that at least one training session be conducted in a pool or sheltered water setting, to cover equipment handling and familiarization, swimming and buoyancy control, to estimate gas consumption rates, and to practice emergency procedures.
3. At least 6 open-water training dives simulating/requiring decompression shall be conducted, emphasizing planning and execution of required decompression dives, and including practice of emergency procedures.
4. Progression to greater depths shall be by 4-dive increments at depth intervals as specified in Section 5.40.
5. No training dives requiring decompression shall be conducted until the diver has demonstrated acceptable skills under simulated conditions.

6. The following are the minimum skills the diver must demonstrate proficiently during dives simulating and requiring decompression:

   - Buoyancy control
   - Proper ascent rate
   - Proper depth control
   - Equipment manipulation
   - Stage/decompression bottle use as pertinent to planned diving operation
   - Buddy skills
   - Gas management
   - Time management
   - Task loading
   - Emergency skills

7. Divers shall demonstrate to the satisfaction of the DSO or the DSO's designee proficiency in planning and executing required decompression dives appropriate to the conditions in which diving operations are to be conducted.

8. Upon completion of training, the diver shall be authorized to conduct required decompression dives with DSO approval.

9.20 Minimum Equipment Requirements

a) Valve and regulator systems for primary (bottom) gas supplies shall be configured in a redundant manner that allows continuous breathing gas delivery in the event of failure of any one component of the regulator/valve system.

b) Cylinders with volume and configuration adequate for planned diving operations.

c) One of the second stages on the primary gas supply shall be configured with a hose of adequate length to facilitate effective emergency gas sharing in the intended environment.

d) Minimum dive equipment shall include:

   1. Snorkel is optional at the DCB's discretion, as determined by the conditions and environment.
   2. Diver location devices adequate for the planned diving operations and environment.
   3. Compass

e) Redundancy in the following components is desirable or required at the discretion of the DCB or DSO:

   1. Decompression Schedules
   2. Dive Timing Devices
   3. Depth gauges
   4. Buoyancy Control Devices
   5. Cutting devices
   6. Lift bags and line reels

9.30 Minimum Operational Requirements

a) Approval of dive plan applications to conduct required decompression dives shall be on a case-by-case basis.

b) The maximum pO_2 to be used for planning required decompression dives is 1.6. It is recommended that a pO_2 of less than 1.6 be used during bottom exposure.

c) Diver's gas supplies shall be adequate to meet planned operational requirements and foreseeable emergency situations.

d) Decompression dives may be planned using dive tables, dive computers, and/or PC software approved by the DSO/DCB.

e) Breathing gases used while performing in-water decompression shall contain the same or greater oxygen content as that used during the bottom phase of the dive.

f) The dive team prior to each dive shall review emergency procedures appropriate for the planned dive.

g) If breathing gas mixtures other than air are used for required decompression, their use shall be in accordance with those regulations set forth in the appropriate sections of this standard.

h) The maximum depth for required decompression using air as the bottom gas shall be 190 feet.

i) Use of additional nitrox and/or high-oxygen fraction decompression mixtures as travel and decompression gases to decrease decompression obligations is encouraged.

j) Use of alternate inert gas mixtures to limit narcosis is encouraged for depths greater than 150 feet.

k) If a period of more than 6 months has elapsed since the last mixed gas dive, a series of progressive workup dives to return the diver(s) to proficiency status prior to the start of project diving operations are recommended.

l) Mission specific workup dives are recommended.

SECTION 10.00 MIXED GAS DIVING

Mixed gas diving is defined as dives done while breathing gas mixes containing proportions greater than 1% by volume of an inert gas other than nitrogen.

10.10 Minimum Experience and Training Requirements

a) Prerequisites:

1. Nitrox certification and authorization (Section 7.00)
2. If the intended use entails required decompression stops, divers will be previously certified and authorized in decompression diving (Section 9.00).
3. Divers shall demonstrate to the DCB's satisfaction skills, knowledge, and attitude appropriate for training in the safe use of mixed gases.

b) Classroom training including:

1. Review of topics and issues previously outlined in nitrox and required decompression diving training as pertinent to the planned operations.
2. The use of helium or other inert gases, and the use of multiple decompression gases.
3. Equipment configurations
4. Mixed gas decompression planning
5. Gas management planning
6. Thermal considerations
7. END determination
8. Mission planning and logistics
9. Emergency procedures
10. Mixed gas production methods
11. Methods of gas handling and cylinder filling
12. Oxygen exposure management
13. Gas analysis
14. Mixed gas physics and physiology

c) Practical Training:

1. Confined water session(s) in which divers demonstrate proficiency in required skills and techniques for proposed diving operations.
2. A minimum of 6 open water training dives.
3. At least one initial dive shall be in 130 feet or less to practice equipment handling and emergency procedures.
4. Subsequent dives will gradually increase in depth, with a majority of the training dives being conducted between 130 feet and the planned operational depth.
5. Planned operational depth for initial training dives shall not exceed 260 feet.
6. Diving operations beyond 260 feet requires additional training dives.

10.20 Equipment and Gas Quality Requirements

a) Equipment requirements shall be developed and approved by the DCB, and met by divers, prior to engaging in mixed-gas diving. Equipment shall meet other pertinent requirements set forth elsewhere in this standard.

b) The quality of inert gases used to produce breathing mixtures shall be of an acceptable grade for human consumption.

10.30 Minimum Operational Requirements

a) Approval of dive plan applications to conduct mixed gas dives shall be on a case-by-case basis.

b) All applicable operational requirements for nitrox and decompression diving shall be met.

c) The maximum pO_2 to be used for planning required decompression dives is 1.6. It is recommended that a pO_2 of less than 1.6 be used during bottom exposure.

d) Maximum planned Oxygen Toxicity Units (OTU) will be considered based on mission duration.

e) Divers decompressing on high-oxygen concentration mixtures shall closely monitor one another for signs of acute oxygen toxicity.

If a period of more than 6 months has elapsed since the last mixed gas dive, a series of progressive workup dives to return the diver(s) to proficiency status prior to the start of project diving operations are recommended.

SECTION 11.00 OTHER DIVING TECHNOLOGY

Certain types of diving, some of which are listed below, require equipment or procedures that require training. Supplementary guidelines for these technologies are in development by the AAUS. Organizational member's using these, must have guidelines established by their Diving Control Board. Divers shall comply with all scuba diving procedures in this standard unless specified.

11.10 Blue Water Diving

Blue water diving is defined as diving in open water where the bottom is generally greater than 200 feet deep. It requires special training and the use of multiple-tethered diving techniques. Specific guidelines that should be followed are outlined in "Blue Water Diving Guidelines" (California Sea Grant Publ. No. T-CSGCP-014).

11.20 Ice And Polar Diving

Divers planning to dive under ice or in polar conditions should use the following: "Guidelines for Conduct of Research Diving", National Science Foundation, Division of Polar Programs, 1990.

11.30 Overhead Environments

Where an enclosed or confined space is not large enough for two divers, a diver shall be stationed at the underwater point of entry and an orientation line shall be used.

11.40 Saturation Diving

If using open circuit compressed air scuba in saturation diving operations, divers shall comply with the saturation diving guidelines of the organizational member.

11.50 Hookah

While similar to Surface Supplied in that the breathing gas is supplied from the surface by means of a pressurized hose, the supply hose does not require a strength member, pneumofathometer hose, or communication line. Hookah equipment may be as simple as a long hose attached to a standard scuba cylinder supplying a standard scuba second stage. The diver is responsible for the monitoring his/her own depth, time, and diving profile.

11.60 Surface Supplied Diving

Surface Supplied: Dives where the breathing gas is supplied from the surface by means of a pressurized umbilical hose. The umbilical generally consists of a gas supply hose, strength member, pneumofathometer hose, and communication line. The umbilical supplies a helmet or full-face mask. The diver may rely on the tender at the surface to keep up with the divers' depth, time and diving profile.

SECTION 12.0 REBREATHERS

This section defines specific considerations regarding the following issues for the use of rebreathers:

- Training and/or experience verification requirements for authorization
- Equipment requirements
- Operational requirements and additional safety protocols to be used

Application of this standard is in addition to pertinent requirements of all other sections of the AAUS Standards for Scientific Diving, Volumes 1 and 2.

For rebreather dives that also involve staged decompression and/or mixed gas diving, all requirements for each of the relevant diving modes shall be met. Diving Control Board reserves the authority to review each application of all specialized diving modes, and include any further requirements deemed necessary beyond those listed here on a case-by-case basis.

No diver shall conduct planned operations using rebreathers without prior review and approval of the DCB.

In all cases, trainers shall be qualified for the type of instruction to be provided. Training shall be conducted by agencies or instructors approved by DSO and DCB.

12.10 Definitions and General Information

a) Rebreathers are defined as any device that recycles some or all of the exhaled gas in the breathing loop and returns it to the diver. Rebreathers maintain levels of oxygen and carbon dioxide that support life by metered injection of oxygen and chemical removal of carbon dioxide. These characteristics fundamentally distinguish rebreathers from open-circuit life support systems, in that the breathing gas composition is dynamic rather than fixed.

1. Advantages of rebreathers may include increased gas utilization efficiencies that are often independent of depth, extended no-decompression bottom times and greater decompression efficiency, and reduction or elimination of exhaust bubbles that may disturb aquatic life or sensitive environments.

2. Disadvantages of rebreathers include high cost and, in some cases, a high degree of system complexity and reliance on instrumentation for gas composition control and monitoring, which may fail. The diver is more likely to experience hazardous levels of hypoxia, hyperoxia, or hypercapnia, due to user error or equipment malfunction, conditions which may lead to underwater blackout and drowning. Inadvertent flooding of the breathing loop and wetting of the carbon dioxide absorbent may expose the diver to ingestion of an alkaline slurry ("caustic cocktail").

3. An increased level of discipline and attention to rebreather system status by the diver is required for safe operation, with a greater need for self-reliance. Rebreather system design and operation varies significantly between make and model. For these reasons when evaluating any dive plan incorporating rebreathers, risk-management emphasis should be placed on the individual qualifications of the diver on the specific rebreather make and model to be used, in addition to specific equipment requirements and associated operational protocols.

b) Oxygen Rebreathers. Oxygen rebreathers recycle breathing gas, consisting of pure oxygen, replenishing the oxygen metabolized by the diver. Oxygen rebreathers are generally the least complicated design, but are normally limited to a maximum operation depth of 20fsw due to the risk of unsafe hyperoxic exposure.

c) Semi-Closed Circuit Rebreathers. Semi-closed circuit rebreathers (SCR) recycle the majority of exhaled breathing gas, venting a portion into the water and replenishing it with a constant or variable amount of a single oxygen-enriched gas mixture. Gas addition and venting is balanced against diver metabolism to maintain safe oxygen levels by means which differ between SCR models, but the mechanism usually provides a semi-constant fraction of oxygen (FO_2) in the breathing loop at all depths, similar to open-circuit SCUBA.

d) Closed-Circuit Mixed Gas Rebreathers. Closed-circuit mixed gas rebreathers (CCR) recycle all of the exhaled gas and replace metabolized oxygen via an electronically controlled valve, governed by electronic oxygen sensors. Manual oxygen addition is available as a diver override, in case of electronic system failure. A separate inert gas source (diluent), usually containing primarily air, heliox, or trimix, is used to maintain oxygen levels at safe levels when diving below 20fsw. CCR systems operate to maintain a constant oxygen partial pressure (PPO_2) during the dive, regardless of depth.

12.20 Prerequisites

Specific training requirements for use of each rebreather model shall be defined by DCB on a case-by-case basis. Training shall include factory-recommended requirements, but may exceed this to prepare for the type of mission intended (e.g., staged decompression or heliox/trimix CCR diving).

Training Prerequisites

a) Active scientific diver status, with depth qualification sufficient for the type, make, and model of rebreather, and planned application.

b) Completion of a minimum of 50 open-water dives on SCUBA.

c) For SCR or CCR, a minimum 100-fsw-depth qualification is generally recommended, to ensure the diver is sufficiently conversant with the complications of deeper diving. If the sole expected application for use of rebreathers is shallower than this, a lesser depth qualification may be allowed with the approval of the DCB.

d) Nitrox training. Training in use of nitrox mixtures containing 25% to 40% oxygen is required. Training in use of mixtures containing 40% to 100% oxygen may be required, as needed for the planned application and rebreather system. Training may be provided as part of rebreather training.

Training

Successful completion of the following training program qualifies the diver for rebreather diving using the system on which the diver was trained, in depths of 130fsw and shallower, for dives that do not require decompression stops, using nitrogen/oxygen breathing media.

a) Satisfactory completion of a rebreather training program authorized or recommended by the manufacturer of the rebreather to be used, or other training approved by the DCB. Successful completion of training does not in itself authorize the diver to use rebreathers. The diver must demonstrate to the DCB or its designee that the diver possesses the proper attitude, judgment, and discipline to safely conduct rebreather diving in the context of planned operations.

b) Classroom training shall include:

1. A review of those topics of diving physics and physiology, decompression management, and dive planning included in prior scientific diver, nitrox, staged decompression and/or mixed gas training, as they pertain to the safe operation of the selected rebreather system and planned diving application.

2. In particular, causes, signs and symptoms, first aid, treatment and prevention of the following must be covered:

- Hyperoxia (CNS and Pulmonary Oxygen Toxicity)
- Middle Ear Oxygen Absorption Syndrome (oxygen ear)
- Hyperoxia-induced myopia
- Hypoxia
- Hypercapnia
- Inert gas narcosis
- Decompression sickness

3. Rebreather-specific information required for the safe and effective operation of the system to be used, including:

- System design and operation, including:
- Counterlung(s)
- CO_2 scrubber
- CO_2 absorbent material types, activity characteristics, storage, handling and disposal
- Oxygen control system design, automatic and manual
- Diluent control system, automatic and manual (if any)
- Pre-dive set-up and testing
- Post-dive break-down and maintenance
- Oxygen exposure management
- Decompression management and applicable decompression tracking methods
- Dive operations planning
- Problem recognition and management, including system failures leading to hypoxia, hyperoxia, hypercapnia, flooded loop, and caustic cocktail
- Emergency protocols and bailout procedures

Practical Training (with model of rebreather to be used)

a) A minimum number of hours of underwater time.

Type	Pool/Confined Water	O/W Training	O/W Supervised
Oxygen Rebreather	1 dive, 90 min	4 dives, 120 min.*	2 dives, 60 min
Semi-Closed Circuit	1 dive, 90-120 min	4 dives, 120 min.**	4 dives, 120 min
Closed-Circuit	1 dive, 90-120 min	8 dives, 380 min.***	4 dives, 240 min

* Dives should not exceed 20 fsw.

** First two dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least o dive in the 80 to 100 fsw range.

*** Total underwater time (pool and open water) of approximately 500 minutes. First two open water dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least 2 dives in the 100 to 130 fsw range.

b) Amount of required in-water time should increase proportionally to the complexity of rebreather system used.

c) Training shall be in accordance with the manufacturer's recommendations.

Practical Evaluations

Upon completion of practical training, the diver must demonstrate to the DCB or its designee proficiency in pre-dive, dive, and post-dive operational procedures for the particular model of rebreather to be used. Skills shall include, at a minimum:

- Oxygen control system calibration and operation checks
- Carbon dioxide absorbent canister packing
- Supply gas cylinder analysis and pressure check
- Test of one-way valves
- System assembly and breathing loop leak testing
- Pre-dive breathing to test system operation
- In-water leak checks
- Buoyancy control during descent, bottom operations, and ascent
- System monitoring and control during descent, bottom operations, and ascent
- Proper interpretation and operation of system instrumentation (PO2 displays, dive computers, gas supply pressure gauges, alarms, etc, as applicable)
- Unit removal and replacement on the surface.
- Bailout and emergency procedures for self and buddy, including:
- System malfunction recognition and solution
- Manual system control
- Flooded breathing loop recovery (if possible)
- Absorbent canister failure
- Alternate bailout options
- Symptom recognition and emergency procedures for hyperoxia, hypoxia, and hypercapnia
- Proper system maintenance, including:
- Full breathing loop disassembly and cleaning (mouthpiece, check-valves, hoses, counterlung, absorbent canister, etc.)
- Oxygen sensor replacement (for SCR and CCR)
- Other tasks required by specific rebreather models

Written Evaluation

A written evaluation approved by the DCB with a pre-determined passing score, covering concepts of both classroom and practical training, is required.

Supervised Rebreather Dives

Upon successful completion of open water training dives, the diver is authorized to conduct a series of supervised rebreather dives, during which the diver gains additional experience and proficiency.

a) Supervisor for these dives should be the DSO or designee, and should be an active scientific diver experienced in diving with the make/model of rebreather being used.

b) Dives at this level may be targeted to activities associated with the planned science diving application. See the following table for number and cumulative water time for different rebreather types.

Type	Pool/Confined Water	O/W Training	O/W Supervised
Oxygen Rebreather	1 dive, 90 min	4 dives, 120 min.*	2 dives, 60 min
Semi-Closed Circuit	1 dive, 90-120 min	4 dives, 120 min.**	4 dives, 120 min
Closed-Circuit	1 dive, 90-120 min	8 dives, 380 min.***	4 dives, 240 min

* Dives should not exceed 20 fsw.

** First two dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least o dive in the 80 to 100 fsw range.

*** Total underwater time (pool and open water) of approximately 500 minutes. First two open water dives should not exceed 60 fsw. Subsequent dives should be at progressively greater depths, with at least 2 dives in the 100 to 130 fsw range.

c) Maximum ratio of divers per designated dive supervisor is 4:1. The supervisor may dive as part of the planned operations.

Extended Range, Required Decompression and Helium-Based Inert Gas

Rebreather dives involving operational depths in excess of 130 fsw, requiring staged decompression, or using diluents containing inert gases other than nitrogen are subject to additional training requirements, as determined by DCB on a case-by-case basis. Prior experience with required decompression and mixed gas diving using open-circuit SCUBA is desirable, but is not sufficient for transfer to dives using rebreathers without additional training.

a) As a prerequisite for training in staged decompression using rebreathers, the diver shall have logged a minimum of 25 hours of underwater time on the rebreather system to be used, with at least 10 rebreather dives in the 100 fsw to 130 fsw range.

b) As a prerequisite for training for use of rebreathers with gas mixtures containing inert gas other than nitrogen, the diver shall have logged a minimum of 50 hours of underwater time on the rebreather system to be used and shall have completed training in stage decompression methods using rebreathers. The diver shall have completed at least 12 dives requiring staged decompression on the rebreather model to be used, with at least 4 dives near 130 fsw.

c) Training shall be in accordance with standards for required-decompression and mixed gas diving, as applicable to rebreather systems, starting at the130 fsw level.

Maintenance of Proficiency

a) To maintain authorization to dive with rebreathers, an authorized diver shall make at least one dive using a rebreather every 8 weeks. For divers authorized for the conduct of extended range, stage decompression or mixed-gas diving, at least one dive per month should be made to a depth near 130 fsw, practicing decompression protocols.

b) For a diver in arrears, the DCB shall approve a program of remedial knowledge and skill tune-up training and a course of dives required to return the diver to full authorization. The extent of this program should be directly related to the complexity of the planned rebreather diving operations.

12.30 Equipment Requirements

General Requirements

a) Only those models of rebreathers specifically approved by DCB shall be used.

b) Rebreathers should be manufactured according to acceptable Quality Control/Quality Assurance protocols, as evidenced by compliance with the essential elements of ISO 9004. Manufacturers should be able to provide to the DCB supporting documentation to this effect.

c) Unit performance specifications should be within acceptable levels as defined by standards of a recognized authority (CE, US Navy, Royal Navy, NOAA, etc…).

d) Prior to approval, the manufacturer should supply the DCB with supporting documentation detailing the methods of specification determination by a recognized third-party testing agency, including unmanned and manned testing. Test data should be from a recognized, independent test facility.

e) The following documentation for each rebreather model to be used should be available as a set of manufacturer's specifications. These should include:

- Operational depth range
- Operational temperature range
- Breathing gas mixtures that may be used
- Maximum exercise level which can be supported as a function of breathing gas and depth
- Breathing gas supply durations as a function of exercise level and depth
- CO_2 absorbent durations, as a function of depth, exercise level, breathing gas, and water temperature
- Method, range and precision of inspired PPO_2 control, as a function of depth, exercise level, breathing gas, and temperature
- Likely failure modes and backup or redundant systems designed to protect the diver if such failures occur
- Accuracy and precision of all readouts and sensors
- Battery duration as a function of depth and temperature
- Mean time between failures of each subsystem and method of determination

f) A complete instruction manual is required, fully describing the operation of all rebreather components and subsystems as well as maintenance procedures.

g) A maintenance log is required. The unit maintenance shall be up-to-date based upon manufacturer's recommendations.

Minimum Equipment

a) A surface/dive valve in the mouthpiece assembly, allowing sealing of the breathing loop from the external environment when not in use.

b) An automatic gas addition valve, so that manual volumetric compensation during descent is unnecessary.

c) Manual gas addition valves, so that manual volumetric compensation during descent and manual oxygen addition at all times during the dive are possible.

d) The diver shall carry alternate life support capability (open-circuit bail-out or redundant rebreather) sufficient to allow the solution of minor problems and allow reliable access to a pre-planned alternate life support system.

Oxygen Rebreathers

Oxygen rebreathers shall be equipped with manual and automatic gas addition valves.

Semi-Closed Circuit Rebreathers.

SCR's shall be equipped with at least one manufacturer-approved oxygen sensor sufficient to warn the diver of impending hypoxia. Sensor redundancy is desirable, but not required.

Closed Circuit Mixed-gas Rebreathers.

a) CCR shall incorporate a minimum of three independent oxygen sensors.

b) A minimum of two independent displays of oxygen sensor readings shall be available to the diver.

c) Two independent power supplies in the rebreather design are desirable. If only one is present, a secondary system to monitor oxygen levels without power from the primary battery must be incorporated.

d) CCR shall be equipped with manual diluent and oxygen addition valves, to enable the diver to maintain safe oxygen levels in the event of failure of the primary power supply or automatic gas addition systems.

e) Redundancies in onboard electronics, power supplies, and life support systems are highly desirable.

12.40 Operational Requirements

General Requirements

a) All dives involving rebreathers must comply with applicable operational requirements for open-circuit SCUBA dives to equivalent depths.

b) No rebreather system should be used in situations beyond the manufacturer's stated design limits (dive depth, duration, water temperature, etc).

c) Modifications to rebreather systems shall be in compliance with manufacturer's recommendations.

d) Rebreather maintenance is to be in compliance with manufacturer's recommendations including sanitizing, replacement of consumables (sensors, CO_2 absorbent, gas, batteries, etc) and periodic maintenance.

e) Dive Plan. In addition to standard dive plan components stipulated in AAUS Section 2.0, all dive plans that include the use of rebreathers must include, at minimum, the following details:

- Information about the specific rebreather model to be used
- Make, model, and type of rebreather system
- Type of CO_2 absorbent material
- Composition and volume(s) of supply gases
- Complete description of alternate bailout procedures to be employed, including manual rebreather operation and open-circuit procedures
- Other specific details as requested by DCB

Buddy Qualifications.

a) A diver whose buddy is diving with a rebreather shall be trained in basic rebreather operation, hazard identification, and assist/rescue procedures for a rebreather diver.

b) If the buddy of a rebreather diver is using open-circuit scuba, the rebreather diver must be equipped with a means to provide the open-circuit scuba diver with a sufficient supply of open-circuit breathing gas to allow both divers to return safely to the surface.

Oxygen Exposures

a) Planned oxygen partial pressure in the breathing gas shall not exceed 1.4 atmospheres at depths greater than 30 feet.

b) Planned oxygen partial pressure set point for CCR shall not exceed 1.4 ata. Set point at depth should be reduced to manage oxygen toxicity according to the NOAA Oxygen Exposure Limits.

c) Oxygen exposures should not exceed the NOAA oxygen single and daily exposure limits. Both CNS and pulmonary (whole-body) oxygen exposure indices should be tracked for each diver.

Decompression Management

a) DCB shall review and approve the method of decompression management selected for a given diving application and project.

b) Decompression management can be safely achieved by a variety of methods, depending on the type and model of rebreather to be used. Following is a general list of methods for different rebreather types:

1. Oxygen rebreathers: Not applicable.

2. SCR (presumed constant FO_2):

   - Use of any method approved for open-circuit scuba diving breathing air, above the maximum operational depth of the supply gas.
   - Use of open-circuit nitrox dive tables based upon expected inspired FO_2. In this case, contingency air dive tables may be necessary for active-addition SCR's in the event that exertion level is higher than expected.
   - Equivalent air depth correction to open-circuit air dive tables, based upon expected inspired FO_2 for planned exertion level, gas supply rate, and gas composition. In this case, contingency air dive tables may be necessary for active-addition SCR's in the event that exertion level is higher than expected.

3. CCR (constant PPO_2):

   - Integrated constant PPO_2 dive computer.
   - Non-integrated constant PPO_2 dive computer.
   - Constant PPO_2 dive tables.
   - Open-circuit (constant FO_2) nitrox dive computer, set to inspired FO_2 predicted using PPO_2 set point at the maximum planned dive depth.
   - Equivalent air depth (EAD) correction to standard open-circuit air dive tables, based on the inspired FO_2 predicted using the PPO_2 set point at the maximum planned dive depth.
   - Air dive computer, or air dive tables used above the maximum operating depth (MOD) of air for the PPO_2 setpoint selected.

Maintenance Logs, CO2 Scrubber Logs, Battery Logs, and Pre-And Post-Dive Checklists

Logs and checklists will be developed for the rebreather used, and will be used before and after every dive. Diver shall indicate by initialing that checklists have been completed before and after each dive. Such documents shall be filed and maintained as permanent project records. No rebreather shall be dived which has failed any portion of the pre-dive check, or is found to not be operating in accordance with manufacturer's specifications. Pre-dive checks shall include:

- Gas supply cylinders full
- Composition of all supply and bail-out gases analyzed and documented
- Oxygen sensors calibrated
- Carbon dioxide canister properly packed
- Remaining duration of canister life verified
- Breathing loop assembled
- Positive and negative pressure leak checks
- Automatic volume addition system working
- Automatic oxygen addition systems working
- Pre-breathe system for 3 minutes (5 minutes in cold water) to ensure proper oxygen addition and carbon dioxide removal (be alert for signs of hypoxia or hypercapnia)
- Other procedures specific to the model of rebreather used
- Documentation of ALL components assembled
- Complete pre-dive system check performed
- Final operational verification immediately before to entering the water:
- PO_2 in the rebreather is not hypoxic
- Oxygen addition system is functioning;
- Volumetric addition is functioning
- Bail-out life support is functioning

Alternate Life Support System

The diver shall have reliable access to an alternate life support system designed to safely return the diver to the surface at normal ascent rates, including any required decompression in the event of primary rebreather failure. The complexity and extent of such systems are directly related to the depth/time profiles of the mission. Examples of such systems include, but are not limited to:

a) Open-circuit bailout cylinders or sets of cylinders, either carried or pre-positioned

b) Redundant rebreather

c) Pre-positioned life support equipment with topside support

CO2 Absorbent Material

a) CO_2 absorption canister shall be filled in accordance with the manufacturer's specifications.

b) CO_2 absorbent material shall be used in accordance with the manufacturer's specifications for expected duration.

c) If CO_2 absorbent canister is not exhausted and storage between dives is planned, the canister should be removed from the unit and stored sealed and protected from ambient air, to ensure the absorbent retains its activity for subsequent dives.

d) Long-term storage of carbon dioxide absorbents shall be in a cool, dry location in a sealed container. Field storage must be adequate to maintain viability of material until use.

Consumables (e.g., batteries, oxygen sensors, etc.)

Other consumables (e.g., batteries, oxygen sensors, etc.) shall be maintained, tested, and replaced in accordance with the manufacturer's specifications.

Unit Disinfections

The entire breathing loop, including mouthpiece, hoses, counterlungs, and CO2 canister, should be disinfected periodically according to manufacturer's specifications. The loop must be disinfected between each use of the same rebreather by different divers.

12.50 Oxygen Rebreathers

a) Oxygen rebreathers shall not be used at depths greater than 20 feet.

b) Breathing loop and diver's lungs must be adequately flushed with pure oxygen prior to entering the water on each dive. Once done, the diver must breathe continuously and solely from the intact loop, or re-flushing is required.

c) Breathing loop shall be flushed with fresh oxygen prior to ascending to avoid hypoxia due to inert gas in the loop.

12.60 Semi-Closed Circuit Rebreathers

a) The composition of the injection gas supply of a semi-closed rebreather shall be chosen such that the partial pressure of oxygen in the breathing loop will not drop below 0.2 ata, even at maximum exertion at the surface.

b) The gas addition rate of active addition SCR (e.g., Draeger Dolphin and similar units) shall be checked before every dive, to ensure it is balanced against expected workload and supply gas FO_2.

c) The intermediate pressure of supply gas delivery in active-addition SCR shall be checked periodically, in compliance with manufacturer's recommendations.

d) Maximum operating depth shall be based upon the FO_2 in the active supply cylinder.

e) Prior to ascent to the surface the diver shall flush the breathing loop with fresh gas or switch to an open-circuit system to avoid hypoxia. The flush should be at a depth of approximately 30 fsw during ascent on dives deeper than 30 fsw, and at bottom depth on dives 30 fsw and shallower.

12.70 Closed-Circuit Rebreathers

a) The FO_2 of each diluent gas supply used shall be chosen so that, if breathed directly while in the depth range for which its use is intended, it will produce an inspired PPO_2 greater than 0.20 ata but no greater than 1.4 ata.

b) Maximum operating depth shall be based on the FO_2 of the diluent in use during each phase of the dive, so as not to exceed a PO_2 limit of 1.4 ata.

c) Divers shall monitor both primary and secondary oxygen display systems at regular intervals throughout the dive, to verify that readings are within limits, that redundant displays are providing similar values, and whether readings are dynamic or static (as an indicator of sensor failure).

d) The PPO_2 set point shall not be lower than 0.4 ata or higher than 1.4 ata.

SECTION 13 SCIENTIFIC CAVE AND CAVERN DIVING STANDARD

This standard helps to ensure all scientific diving in overhead environments is conducted in a manner which will maximize the protection of scientific divers from accidental injury and/or illness and provide the basis allowing the working reciprocity between AAUS organizational members.

If a conflict exists between this standard and other standards in this manual, the information set forth in this standard only takes precedence when the scientific diving being conducted takes place wholly or partly within an underwater cave or cavern environment.

A dive team shall be considered to be cave or cavern diving if at any time during the dive they find themselves in a position where they cannot complete a direct, unobstructed ascent to the surface because of rock formations.

The member organization requires that no person shall engage in scientific cave or cavern diving unless that person holds a recognized certificate/authorization issued pursuant to the provisions of this manual.

The diver must demonstrate to the DCB or its designee that the diver possesses the proper attitude, judgment, and discipline to safety conduct cave and cavern diving in the context of planned operations.

Operational requirements for cave and cavern diving have been established through accident analysis of previous cave diving accidents.

13.1 Definitions

Alternate Gas Supply - Fully redundant system capable of providing a gas source to the diver should their primary gas supply fail.

Bubble Check - Visual examination by the dive team of their diving systems, looking for o-ring leaks or other air leaks conducted in the water prior to entering a cave. Usually included in the "S" Drill.

Cave – A dive shall be considered a cave dive if any one or more of the environmental limits specified in the definition of cavern are exceeded or otherwise not followed. Linear penetrations limits shall not exceed the limits of each diver's training.

Cave Dive - A dive, which takes place partially or wholly underground, in which one or more of the environmental parameters defining a cavern dive are exceeded.

Cavern - An entrance and first chamber to a cave where:

1. Sunlight from the entrance is visible to all dive team members at all times during the dive.
2. Members of the dive team do not pass through any restrictions that don't allow the divers to swim side by side during the dive, nor are there any restrictions between the divers and the most expeditious exit to the surface.
3. Maximum depth achieved shall not exceed the depth ratings of dive team.

Cavern Dive - A dive which takes place partially or wholly underground, in which the following environmental parameters are met:

1. Natural sunlight is continuously visible from the entrance.
2. Environmental conditions will be evaluated by the DSO or designee and appropriate limits incorporated into the dive plan.

Dual Valve Manifold with Isolator Valve - A manifold joining two diving cylinders, that allows the use of two completely independent regulators. If either regulator fails, it may be shut off, allowing the remaining regulator access to the gas in both of the diving cylinders.

Gas Management - Gas planning rule which is used in cave diving environments in which the diver reserves a portion of their available breathing gas for anticipated emergencies (See Rule of Thirds, Sixths).

Guideline - Continuous line used as a navigational reference during a dive leading from the team position to a point where a direct vertical ascent may be made to the surface.

Jump/Gap Reel -Spool or reel used to connect one guide line to another thus ensuring a continuous line to the exit.

Knife/Line Cutter - Small, sharp blade capable of easily cutting a guideline and that is accessible to the diver.

Lava Tube - Type of cave or cavern formed by the surface hardening of a stream of flowing molten rock, which may later become flooded due to static sea level changes.

Line Marker - Any one of several types of markers attached to a guideline, which provides additional navigational information to the dive team, most commonly the direction out to the nearest surface.

Mine Diving - Diving in the flooded portions of a man-made mine. Necessitates use of techniques detailed for cave diving.

Penetration Distance - Linear distance from the entrance intended or reached by a dive team during a dive at a dive site.

Primary Reel - Initial guideline used by the dive team from open water to maximum penetration or a permanently installed guideline.

Restriction - Any passage through which two divers cannot easily pass side by side while sharing air.

Rule of Thirds - Gas planning rule which is used in cave diving environments in which the diver reserves 2/3's of their breathing gas supply for exiting the cave or cavern.

Rule of Sixths - Air planning rule which is used in cave or other confined diving environments in which the diver reserves 5/6's of their breathing gas supply (for DPV use, siphon diving, etc.) for exiting the cave or cavern.

Safety Drill - ("S" Drill) - Short gas sharing, equipment evaluation, dive plan, and communication exercise carried out prior to entering a cave or cavern dive by the dive team.

Safety Reel - Secondary reel used as a backup to the primary reel, usually containing 150 feet of guideline that is used in an emergency.

Scientific Cave or Cavern Diver In Training - Authorized to dive in the cave or cavern environment under the direct supervision of qualified instructional personnel for training purposes only.

Scientific Cavern Diver - Authorization to dive in an overhead environment as defined in cavern.

Scientific Cave Diver - Authorization to dive in an overhead environment as defined in cave.

Sidemount Diving - A diving mode utilizing two independent SCUBA systems carried along the sides of the diver's body; either of which always has sufficient air to allow the diver to reach the surface unassisted.

Siphon - Cave into which water flows with a generally continuous in-current.

Solution Cave - Cave formed in carbonate or carbonate-cemented bedrock, formed by the dissolution of the rock by groundwater.

Spring - Cave with water flowing with a generally continuous outflow.

Sump - An area in a dry cave that can no longer be negotiated without the use of diving equipment.

Well - A vertical or nearly vertical shaft, usually manmade, through which a diver can access a dive site.

13.2 Cave and Cavern Environment Hazards

Current/Flow - Underwater caves have currents that vary in strength and direction. Of particular note is a condition known as siphoning. Siphoning caves have flow or current directed into the cave. This can cause poor visibility as a result of mud and silt being drawn into the cave entrance.

Silt - The presences of silt, sand, mud, clay, etc. on the cave floor can cause visibility to be reduced to nothing in a very short time.

Restrictions - Any passage through which two divers cannot easily pass side by side while sharing air make air sharing difficult.

Cave-ins - Cave-ins are a normal part of cave evolution; however experiencing a cave-in during diving operations is extremely unlikely.

13.3 Minimum Experience and Training Requirements

a) Cavern Diver

1. Prerequisites

   The applicant for training shall have met the requirements in Section 5.00 of the AAUS *Standards for Scientific Diving Certification and Operation of Scientific Diving Programs*, fourth edition (2003), and hold as a minimum a scientific diver permit.

2. Cavern Training

   The applicant is to participate in the following areas of training, or their equivalent:

   - Classroom Lecture and Critique—The applicant shall participate in classroom discussion or equivalent type activities covering these topics: Policy for cavern diving, cavern environment and environmental hazards, accident analysis, psychological considerations, equipment, body control, communications, cavern diving techniques, navigation and guidelines, dive planning, cave geology, cave hydrology, cave biology, and emergency procedures.
   - Land Drills—The applicant shall participate in drills above water using the guideline and reel. Drills are to emphasize proper use of the reel, techniques and considerations for laying a guideline, guideline following, buddy communication, and emergency procedures.

- Cavern Dives—A minimum of four (4) cavern dives, preferably to be conducted in a minimum of two (2) different caverns. Skills the applicant should demonstrate include: Safety drill (S-drill), gear matching, bubble check prior to entering the cavern on each dive, proper buoyancy compensator use, proper trim and body positioning, hovering and buoyancy with hand tasks, specialized propulsion techniques (modified flutter kick, modified frog kick, pull and glide, ceiling walk or shuffle), proper guideline and reel use, ability to follow the guideline with no visibility, sharing air while following a guideline, and sharing air while following the guideline with no visibility light and hand signal use, and ability to comfortably work in a cavern without assistance.
- Written Examination - A written evaluation approved by the DCB with a predetermined passing score, covering concepts of both classroom and practical training is required.

b) Cave Diver

1. Prerequisites

The applicant for training shall hold as a minimum a cavern diver permit.

2. Cave Training

The applicant is to participate in the following areas of training, or their equivalent:

Classroom Lecture and Critique—The applicant shall participate in classroom discussion or equivalent type activities covering these topics: Review of the topics listed in cavern diver training and differing techniques and procedures used in cave diving, additional equipment procedures used in cave diving, cave diving equipment configurations, procedures for conducting diving operations involving complex navigation and use of line markers, advanced gas management and a thorough review of dive tables, decompression tables, and decompression theory.

- Land Drills—The applicant shall participate in drills above water included in cavern training. Drills are to emphasize proper use of the reel in lost diver procedures, as well as line placements and station location as required for surveying.
- Cave Dives—A minimum of twelve (12) cave dives, to be conducted in a minimum of four (4) different cave sites with differing conditions recommended. Skills the applicant should demonstrate include: Review of skills listed in cavern training, and special techniques in buoyancy control, referencing and back-up navigation, air sharing in a minor restriction using a single file method, special propulsion techniques in heavy outflow, anti-silting techniques, line jumping techniques and protocols, surveying, and ability to critique their dives. Emergency procedures training shall include proficiency in lost line, lost diver, gas sharing, light failure, valve manipulation, and no/low visibility situations.
- Written Examination - A written evaluation approved by the DCB with a predetermined passing score, covering concepts of both classroom and practical training is required.

13.4 Equipment Requirements

Equipment used for SCUBA in cave or cavern diving is based on the concept of redundancy. Redundant SCUBA equipment shall be carried whenever the planned penetration distances are such that an emergency swimming ascent is not theoretically possible.

a) Cavern Diving Equipment

The following equipment shall be required, in excess of that detailed for open water SCUBA diving in Volume 1, Section 3.00. Each member of the dive team shall have:

- At minimum, a single tank equipped with an "H" valve or an alternate air supply.
- A BCD capable of being inflated from the tank.
- Slate and pencil.
- Two battery powered secondary lights of an approved type.
- Knife or line cutter.
- One primary reel of at least 350 feet for each team.
- Snorkel—No snorkel shall be worn while inside underwater cave or cavern.

b) Cave Diving Equipment

The following equipment shall be required, in excess of that detailed for cavern diving: Each member of the dive team shall have:

- Cylinders with dual orifice isolation valve manifold or independent SCUBA systems each capable of maintaining enough gas for the diver during exit and ascent to the surface.
- Two completely independent regulators, at least one of each having submersible tank pressure gauge, a five foot or longer second stage hose, low pressure inflator for the BCD.
- A primary light with sufficient burn time for the planned dive.
- Safety reel with at least 150 feet of line.
- Appropriate submersible dive tables and/or dive computer (computers w/ backup tables).
- Line markers.
- Snorkel—No snorkel shall be worn while inside underwater cave or cavern.

13.5 Operational Requirements and Safety Protocols

All members of the dive team must have met the applicable all sections of Volume One and applicable sections of Volume Two of the AAUS manual and be authorized for that type of diving by the DCB before conducting scientific cave dives.

a) Cavern Diver Procedures

- Cavern diving shall not be conducted at depths greater than 100 feet.
- Dive teams shall perform a safety drill prior to each cave or cavern penetration that includes equipment check, gas management, and dive objectives.
- Each team within the cavern zone must utilize a continuous guideline appropriate for the environment leading to a point from which an uninterrupted ascent to the surface may be made.
- Gas management must be appropriate for the planned dive with special considerations made for; DPV's, siphon diving, rebreathers, etc.
- The entire dive team is to immediately terminate the dive whenever any dive team member feels an unsafe condition is present.

b) Cave Diving Procedures

- Dive teams shall perform a safety drill prior to each cave or cavern penetration that includes equipment check, gas management, and dive objectives.
- Diver teams must run or follow a continuous guideline from the surface pool to maximum penetration.
- Gas management must be appropriate for the planned dive with special considerations made for: DPV's, siphon diving, rebreathers, etc.
- Each diver must carry one primary and two back up lights.
- Divers utilizing side mount diving or other dual independent diving systems must have the approval of the Diving Safety Officer or his/her designee.
- The entire dive team is to immediately terminate the dive whenever any dive team member feels an unsafe condition is present.

Appendices

Appendix 1 through 9
Required For All Organizational Members

APPENDIX 1
DIVING MEDICAL EXAM OVERVIEW FOR THE EXAMINING PHYSICIAN

TO THE EXAMINING PHYSICIAN:

This person, ______________________, requires a medical examination to assess their fitness for certification as a Scientific Diver for the________________________ (Organizational Member). Their answers on the Diving Medical History Form (attached) may indicate potential health or safety risks as noted. Your evaluation is requested on the attached scuba Diving Fitness Medical Evaluation Report. If you have questions about diving medicine, you may wish to consult one of the references on the attached list or contact one of the physicians with expertise in diving medicine whose names and phone numbers appear on an attached list, the Undersea Hyperbaric and Medical Society, or the Divers Alert Network. Please contact the undersigned Diving Safety Officer if you have any questions or concerns about diving medicine or the ___________________________ standards. Thank you for your assistance.
Organizational Member

________________________________	________________________
Diving Safety Officer	Date
________________________________	________________________
Printed Name	Phone Number

Scuba and other modes of compressed-gas diving can be strenuous and hazardous. A special risk is present if the middle ear, sinuses, or lung segments do not readily equalize air pressure changes. The most common cause of distress is eustachian insufficiency. Recent deaths in the scientific diving community have been attributed to cardiovascular disease. Please consult the following list of conditions that usually restrict candidates from diving.
(Adapted from Bove, 1998: bracketed numbers are pages in Bove)

CONDITIONS WHICH MAY DISQUALIFY CANDIDATES FROM DIVING

1. Abnormalities of the tympanic membrane, such as perforation, presence of a monomeric membrane, or inability to autoinflate the middle ears. [5 ,7, 8, 9]
2. Vertigo, including Meniere's Disease. [13]
3. Stapedectomy or middle ear reconstructive surgery. [11]
4. Recent ocular surgery. [15, 18, 19]
5. Psychiatric disorders including claustrophobia, suicidal ideation, psychosis, anxiety states, untreated depression. [20 - 23]
6. Substance abuse, including alcohol. [24 - 25]
7. Episodic loss of consciousness. [1, 26, 27]
8. History of seizure. [27, 28]
9. History of stroke or a fixed neurological deficit. [29, 30]
10. Recurring neurologic disorders, including transient ischemic attacks. [29, 30]
11. History of intracranial aneurysm, other vascular malformation or intracranial hemorrhage. [31]
12. History of neurological decompression illness with residual deficit. [29, 30]
13. Head injury with sequelae. [26, 27]
14. Hematologic disorders including coagulopathies. [41, 42]
15. Evidence of coronary artery disease or high risk for coronary artery disease. [33 - 35]
16. Atrial septal defects. [39]
17. Significant valvular heart disease - isolated mitral valve prolapse is not disqualifying. [38]
18. Significant cardiac rhythm or conduction abnormalities. [36 - 37]
19. Implanted cardiac pacemakers and cardiac defibrillators (ICD). [39, 40]
20. Inadequate exercise tolerance. [34]
21. Severe hypertension. [35]
22. History of spontaneous or traumatic pneumothorax. [45]
23. Asthma. [42 - 44]
24. Chronic pulmonary disease, including radiographic evidence of pulmonary blebs, bullae, or cysts. [45,46]
25. Diabetes mellitus. [46 - 47]
26. Pregnancy. [56]

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- U.S. NAVY DIVING MANUAL. Superintendent of Documents, Washington, DC: U.S. Government Printing Office, Washington, D.C.

APPENDIX 2
AAUS MEDICAL EVALUATION OF FITNESS FOR SCUBA DIVING REPORT

____ ______________________________

Name of Applicant (Print or Type)   Date of Medical Evaluation (Month/Day/Year)

To The Examining Physician: Scientific divers require periodic scuba diving medical examinations to assess their fitness to engage in diving with self-contained underwater breathing apparatus (scuba). Their answers on the Diving Medical History Form may indicate potential health or safety risks as noted. Scuba diving is an activity that puts unusual stress on the individual in several ways. Your evaluation is requested on this Medical Evaluation form. Your opinion on the applicant's medical fitness is requested. Scuba diving requires heavy exertion. The diver must be free of cardiovascular and respiratory disease (see references, following page). An absolute requirement is the ability of the lungs, middle ears and sinuses to equalize pressure. Any condition that risks the loss of consciousness should disqualify the applicant. Please proceed in accordance with the AAUS Medical Standards (Sec. 6.00). If you have questions about diving medicine, please consult with the Undersea Hyperbaric Medical Society or Divers Alert Network.

TESTS: THE FOLLOWING TESTS ARE <u>REQUIRED</u>:

DURING ALL INITIAL AND PERIODIC RE-EXAMS (UNDER AGE 40):

- Medical history
- Complete physical exam, with emphasis on neurological and otological components
- Urinalysis
- Any further tests deemed necessary by the physician

ADDITIONAL TESTS DURING FIRST EXAM OVER AGE 40 AND PERIODIC RE-EXAMS (OVER AGE 40):

- Chest x-ray (Required only during first exam over age 40)
- Resting EKG
- Assessment of coronary artery disease using Multiple-Risk-Factor Assessment[1]
  (age, lipid profile, blood pressure, diabetic screening, smoking)
  Note: Exercise stress testing may be indicated based on Multiple-Risk-Factor Assessment[2]

PHYSICIAN'S STATEMENT:

_______ 01 Diver **<u>IS</u>** medically qualified to dive for: _______________2 years (over age 60)
_______________3 years (age 40-59)
_______________5 years (under age 40)

_______ 02 Diver **<u>IS NOT</u>** medically qualified to dive:_____________Permanently_______Temporarily.

I have evaluated the abovementioned individual according to the American Academy of Underwater Sciences medical standards and required tests for scientific diving (Sec. 6.00 and Appendix 1) and, in my opinion, find no medical conditions that may be disqualifying for participation in scuba diving. I have discussed with the patient any medical condition(s) that would not disqualify him/her from diving but which may seriously compromise subsequent health. The patient understands the nature of the hazards and the risks involved in diving with these conditions.

____ MD or DO ______________________________

Signature   Date

____

Name (Print or Type)

____

Address

______________________________ ____

Telephone Number   E-Mail Address

My familiarity with applicant is: _____This exam only _____Regular physician for _______ years

My familiarity with diving medicine is: ____

APPENDIX 2b
AAUS MEDICAL EVALUATION OF FITNESS FOR SCUBA DIVING REPORT

APPLICANT'S RELEASE OF MEDICAL INFORMATION FORM

____
Name of Applicant (Print or Type)

I authorize the release of this information and all medical information subsequently acquired in association with my diving to the __________________________________ Diving Safety Officer and Diving Control Board or their designee at (place) ______________________________________ on (date) ___________________________

Signature of Applicant ____ Date___________________

REFERENCES

[1] Grundy, S.M., Pasternak, R., Greenland, P., Smith, S., and Fuster, V. 1999. Assessment of Cardiovascular Risk by Use of Multiple-Risk-Factor Assessment Equations. AHA/ACC Scientific Statement. *Journal of the American College of Cardiology*, 34: 1348-1359. http://content.onlinejacc.org/cgi/content/short/34/4/1348

APPENDIX 3
DIVING MEDICAL HISTORY FORM

(To Be Completed By Applicant-Diver)

Name ______________________________________ Sex ____ Age ___ Wt.___ Ht. ___

Sponsor ____ Date ___/___/___
(Dept./Project/Program/School, etc.) (Mo/Day/Yr)

TO THE APPLICANT:

Scuba diving places considerable physical and mental demands on the diver. Certain medical and physical requirements must be met before beginning a diving or training program. Your accurate answers to the questions are more important, in many instances, in determining your fitness to dive than what the physician may see, hear or feel as part of the diving medical certification procedure.

This form shall be kept confidential by the examining physician. If you believe any question amounts to invasion of your privacy, you may elect to omit an answer, provided that you shall subsequently discuss that matter with your own physician who must then indicate, in writing, that you have done so and that no health hazard exists.

Should your answers indicate a condition, which might make diving hazardous, you will be asked to review the matter with your physician. In such instances, their written authorization will be required in order for further consideration to be given to your application. If your physician concludes that diving would involve undue risk for you, remember that they are concerned only with your well-being and safety.

	Yes	No	Please indicate whether or not the following apply to you	Comments
1			Convulsions, seizures, or epilepsy	
2			Fainting spells or dizziness	
3			Been addicted to drugs	
4			Diabetes	
5			Motion sickness or sea/air sickness	
6			Claustrophobia	
7			Mental disorder or nervous breakdown	
8			Are you pregnant?	
9			Do you suffer from menstrual problems?	
10			Anxiety spells or hyperventilation	
11			Frequent sour stomachs, nervous stomachs or vomiting spells	
12			Had a major operation	
13			Presently being treated by a physician	
14			Taking any medication regularly (even non-prescription)	
15			Been rejected or restricted from sports	
16			Headaches (frequent and severe)	
17			Wear dental plates	

	Yes	No	Please indicate whether or not the following apply to you	Comments
18			Wear glasses or contact lenses	
19			Bleeding disorders	
20			Alcoholism	
21			Any problems related to diving	
22			Nervous tension or emotional problems	
23			Take tranquilizers	
24			Perforated ear drums	
25			Hay fever	
26			Frequent sinus trouble, frequent drainage from the nose, post-nasal drip, or stuffy nose	
27			Frequent earaches	
28			Drainage from the ears	
29			Difficulty with your ears in airplanes or on mountains	
30			Ear surgery	
31			Ringing in your ears	
32			Frequent dizzy spells	
33			Hearing problems	
34			Trouble equalizing pressure in your ears	
35			Asthma	
36			Wheezing attacks	
37			Cough (chronic or recurrent)	
38			Frequently raise sputum	
39			Pleurisy	
40			Collapsed lung (pneumothorax)	
41			Lung cysts	
42			Pneumonia	
43			Tuberculosis	

	Yes	No	Please indicate whether or not the following apply to you	Comments
44			Shortness of breath	
45			Lung problem or abnormality	
46			Spit blood	
47			Breathing difficulty after eating particular foods, after exposure to particular pollens or animals	
48			Are you subject to bronchitis	
49			Subcutaneous emphysema (air under the skin)	
50			Air embolism after diving	
51			Decompression sickness	
52			Rheumatic fever	
53			Scarlet fever	
54			Heart murmur	
55			Large heart	
56			High blood pressure	
57			Angina (heart pains or pressure in the chest)	
58			Heart attack	
59			Low blood pressure	
60			Recurrent or persistent swelling of the legs	
61			Pounding, rapid heartbeat or palpitations	
62			Easily fatigued or short of breath	
63			Abnormal EKG	
64			Joint problems, dislocations or arthritis	
65			Back trouble or back injuries	
66			Ruptured or slipped disk	
67			Limiting physical handicaps	
68			Muscle cramps	
69			Varicose veins	

	Yes	No	Please indicate whether or not the following apply to you	Comments
70			Amputations	
71			Head injury causing unconsciousness	
72			Paralysis	
73			Have you ever had an adverse reaction to medication?	
74			Do you smoke?	
75			Have you ever had any other medical problems not listed? If so, please list or describe below;	
76			Is there a family history of high cholesterol?	
77			Is there a family history of heart disease or stroke?	
78			Is there a family history of diabetes?	
79			Is there a family history of asthma?	
80			Date of last tetanus shot? Vaccination dates?	

Please explain any "yes" answers to the above questions.

____

I certify that the above answers and information represent an accurate and complete description of my medical history.

Signature Date

APPENDIX 4
RECOMMENDED PHYSICIANS WITH EXPERTISE IN DIVING MEDICINE

List of local Medical Doctors that have training and expertise in diving or undersea medicine. Level I graduates of the Undersea Hyperbaric and Medical Society (UHMS) Fitness to Dive courses (approximately 250 physicians) are listed at http://membership.uhms.org/?page=DivingMedical (UHMS website, go to Resources, go to Library, go to Diving Medical Examiners)

1. Name:____
   Address:____
   ____
   Telephone: ____

2. Name:____
   Address:____
   ____
   Telephone: ____

3. Name:____
   Address:____
   ____
   Telephone: ____

4. Name:____
   Address:____
   ____
   Telephone: ____

5. Name:____
   Address:____
   ____
   Telephone: ____

APPENDIX 5
DEFINITION OF TERMS

Air sharing - Sharing of an air supply between divers.

ATA(s) - "Atmospheres Absolute", Total pressure exerted on an object, by a gas or mixture of gases, at a specific depth or elevation, including normal atmospheric pressure.

Breath-hold Diving - A diving mode in which the diver uses no self-contained or surface-supplied air or oxygen supply.

Buddy Breathing - Sharing of a single air source between divers.

Buddy Diver - Second member of the dive team.

Buddy System -Two comparably equipped scuba divers in the water in constant communication.

Buoyant Ascent - An ascent made using some form of positive buoyancy.

Burst Pressure - Pressure at which a pressure containment device would fail structurally.

Certified Diver - A diver who holds a recognized valid certification from an organizational member or internationally recognized certifying agency.

Controlled Ascent - Any one of several kinds of ascents including normal, swimming, and air sharing ascents where the diver(s) maintain control so a pause or stop can be made during the ascent.

Cylinder - A pressure vessel for the storage of gases.

Decompression Chamber - A pressure vessel for human occupancy. Also called a hyperbaric chamber or decompression chamber.

Decompression Sickness - A condition with a variety of symptoms, which may result from gas, and bubbles in the tissues of divers after pressure reduction.

Dive - A descent into the water, an underwater diving activity utilizing compressed gas, an ascent, and return to the surface.

Dive Computer- A microprocessor based device which computes a diver's theoretical decompression status, in real time, by using pressure (depth) and time as input to a decompression model, or set of decompression tables, programmed into the device.

Dive Location - A surface or vessel from which a diving operation is conducted.

Dive Site - Physical location of a diver during a dive.

Dive Table - A profile or set of profiles of depth-time relationships for ascent rates and breathing mixtures to be followed after a specific depth-time exposure or exposures.

Diver - An individual in the water who uses apparatus, including snorkel, which supplies breathing gas at ambient pressure.

Diver-In-Training - An individual gaining experience and training in additional diving activities under the supervision of a dive team member experienced in those activities.

Diver-Carried Reserve Breathing Gas - A diver-carried independent supply of air or mixed gas (as appropriate) sufficient under standard operating conditions to allow the diver to reach the surface, or another source of breathing gas, or to be reached by another diver.

Diving Mode - A type of diving required specific equipment, procedures, and techniques, for example, snorkel, scuba, surface-supplied air, or mixed gas.

Diving Control Board (DCB) - Group of individuals who act as the official representative of the membership organization in matters concerning the scientific diving program (Section 1.24).

Diving Safety Officer (DSO) - Individual responsible for the safe conduct of the scientific diving program of the membership organization (Section 1.20).

EAD - Equivalent Air Depth (see below).

Emergency Ascent - An ascent made under emergency conditions where the diver exceeds the normal ascent rate.

Enriched Air (EANx) - A name for a breathing mixture of air and oxygen when the percent of oxygen exceeds 21%. This term is considered synonymous with the term "nitrox" (Section 7.00).

Equivalent Air Depth (EAD) - Depth at which air will have the same nitrogen partial pressure as the nitrox mixture being used. This number, expressed in units of feet seawater or saltwater, will always be less than the actual depth for any enriched air mixture.

fN_2 - Fraction of nitrogen in a gas mixture, expressed as either a decimal or percentage, by volume.

fO_2 - Fraction of oxygen in a gas mixture, expressed as either a decimal or percentage, by volume.

FFW – Feet or freshwater, or equivalent static head.

FSW - Feet of seawater, or equivalent static head.

Hookah - While similar to Surface Supplied in that the breathing gas is supplied from the surface by means of a pressurized hose, the supply hose does not require a strength member, pneumofathometer hose, or communication line. Hookah equipment may be as simple as a long hose attached to a standard scuba cylinder supplying a standard scuba second stage. The diver is responsible for the monitoring his/her own depth, time, and diving profile.

Hyperbaric Chamber - See decompression chamber.

Hyperbaric Conditions - Pressure conditions in excess of normal atmospheric pressure at the dive location.

Lead Diver - Certified scientific diver with experience and training to conduct the diving operation.

Maximum Working Pressure - Maximum pressure to which a pressure vessel may be exposed under standard operating conditions.

Organizational Member - An organization which is a current member of the AAUS, and which has a program, which adheres to the standards of the AAUS as, set forth in the AAUS Standards for Scientific Diving Certification and Operation of Scientific Diving Programs.

Mixed Gas - MG

Mixed-Gas Diving - A diving mode in which the diver is supplied in the water with a breathing gas other than air.

MOD - Maximum Operating Depth, usually determined as the depth at which the pO_2 for a given gas mixture reaches a predetermined maximum.

MSW - Meters of seawater or equivalent static head.

Nitrox - Any gas mixture comprised predominately of nitrogen and oxygen, most frequently containing between 21% and 40% oxygen. Also be referred to as Enriched Air Nitrox, abbreviated EAN.

NOAA Diving Manual: Refers to the *NOAA Diving Manual, Diving for Science and Technology*, 2001 edition. National Oceanic and Atmospheric Administration, Office of Undersea Research, US Department of Commerce.

No-Decompression limits - Depth-time limits of the “no-decompression limits and repetitive dive group designations table for no-decompression air dives” of the U.S. Navy Diving Manual or equivalent limits.

Normal Ascent - An ascent made with an adequate air supply at a rate of 60 feet per minute or less.

Oxygen Clean - All combustible contaminants have been removed.

Oxygen Compatible - A gas delivery system that has components (o-rings, valve seats, diaphragms, etc.) that are compatible with oxygen at a stated pressure and temperature.

Oxygen Service - A gas delivery system that is both oxygen clean and oxygen compatible.

Oxygen Toxicity Unit - OTU

Oxygen Toxicity - Any adverse reaction of the central nervous system (“acute” or “CNS” oxygen toxicity) or lungs (“chronic”, “whole-body”, or “pulmonary” oxygen toxicity) brought on by exposure to an increased (above atmospheric levels) partial pressure of oxygen.

Pressure-Related Injury - An injury resulting from pressure disequilibrium within the body as the result of hyperbaric exposure. Examples include: decompression sickness, pneumothorax, mediastinal emphysema, air embolism, subcutaneous emphysema, or ruptured eardrum.

Pressure Vessel - See cylinder.

pN_2 - Inspired partial pressure of nitrogen, usually expressed in units of atmospheres absolute.

pO_2 - Inspired partial pressure of oxygen, usually expressed in units of atmospheres absolute.

Psi - Unit of pressure, “pounds per square inch.

Psig - Unit of pressure, “pounds per square inch gauge.

Recompression Chamber - see decompression chamber.

Scientific Diving - Scientific diving is defined (29CFR1910.402) as diving performed solely as a necessary part of a scientific, research, or educational activity by employees whose sole purpose for diving is to perform scientific research tasks.

Scuba Diving - A diving mode independent of surface supply in which the diver uses open circuit self-contained underwater breathing apparatus.

Standby Diver - A diver at the dive location capable of rendering assistance to a diver in the water.

Surface Supplied Diving - Surface Supplied: Dives where the breathing gas is supplied from the surface by means of a pressurized umbilical hose. The umbilical generally consists of a gas supply hose, strength member, pneumofathometer hose, and communication line. The umbilical supplies a helmet or full-face mask. The diver may rely on the tender at the surface to keep up with the divers’ depth, time and diving profile.

Swimming Ascent - An ascent, which can be done under normal or emergency conditions accomplished by simply swimming to the surface.

Umbilical - Composite hose bundle between a dive location and a diver or bell, or between a diver and a bell, which supplies a diver or bell with breathing gas, communications, power, or heat, as appropriate to the diving mode or conditions, and includes a safety line between the diver and the dive location.

Working Pressure - Normal pressure at which the system is designed to operate.

APPENDIX 6

AAUS REQUEST FOR DIVING RECIPROCITY FORM
VERIFICATION OF DIVER TRAINING AND EXPERIENCE

Diver:_______________________________ Date:______________

This letter serves to verify that the above listed person has met the training and pre-requisites as indicated below, and has completed all requirements necessary to be certified as a *(Scientific Diver / Diver in Training)* as established by the *(Organizational Member)* Diving Safety Manual, and has demonstrated competency in the indicated areas. (Organizational Member*)* is an AAUS OM and meets or exceeds all AAUS training requirements.

The following is a brief summary of this diver's personnel file regarding dive status at

____

(Date)

________ Original diving authorization

________ Written scientific diving examination

________ Last diving medical examination Medical examination expiration date_______________

________ Most recent checkout dive

________ Scuba regulator/equipment service/test

________ CPR training (Agency) ___________________ CPR Exp. _________________

________ Oxygen administration (Agency) ___________________ 02 Exp. ___________________

________ First aid for diving ___________________ F.A. Exp. _________________

________ Date of last dive _________ Depth

Number of dives completed within previous 12 months?______ Depth Certification________ fsw

Total number of career dives? _________

Any restrictions? (Y/N)______ if yes, explain:

Please indicate any pertinent specialty certifications or training:

Emergency Information:

Name: Relationship:

Telephone: (work) (home)

Address:

This is to verify that the above individual is currently a certified scientific diver at ________________

Diving Safety Officer:

____ ____________________

(Signature) (Date)

____ ____________________________________

(Print)

APPENDIX 7
DIVING EMERGENCY MANAGEMENT PROCEDURES

Introduction
A diving accident victim could be any person who has been breathing air underwater regardless of depth. It is essential that emergency procedures are pre-planned and that medical treatment is initiated as soon as possible. It is the responsibility of each AAUS organizational member to develop procedures for diving emergencies including evacuation and medical treatment for each dive location.

General Procedures
Depending on and according to the nature of the diving accident:

1. Make appropriate contact with victim or rescue as required.
2. Establish (A)irway, (B)reathing, (C)irculation as required.
3. Stabilize the victim
3. Administer 100% oxygen, if appropriate (in cases of Decompression Illness, or Near Drowning).
4. Call local Emergency Medical System (EMS) for transport to nearest medical treatment facility. Explain the circumstances of the dive incident to the evacuation teams, medics and physicians. Do not assume that they understand why 100% oxygen may be required for the diving accident victim or that recompression treatment may be necessary.
5. Call appropriate Diving Accident Coordinator for contact with diving physician and decompression chamber. etc.
6. Notify DSO or designee according to the Emergency Action Plan of the organizational member.
7. Complete and submit Incident Report Form (www.aaus.org) to the DCB of the organization and the AAUS (Section 2.70 Required Incident Reporting).

List of Emergency Contact Numbers Appropriate For Dive Location

____

Available Procedures

- Emergency care
- Recompression
- Evacuation

Emergency Plan Content

- Name, telephone number, and relationship of person to be contacted for each diver in the event of an emergency.
- Nearest operational decompression chamber.
- Nearest accessible hospital.
- Available means of transport.

APPENDIX 8
DIVE COMPUTER GUIDELINES

1. Only those makes and models of dive computers specifically approved by the Diving Control Board may be used.

2. Any diver desiring the approval to use a dive computer as a means of determining decompression status must apply to the Diving Control Board, complete an appropriate practical training session and pass a written examination.

3. Each diver relying on a dive computer to plan dives and indicate or determine decompression status must have his/her own unit.

4. On any given dive, both divers in the buddy pair must follow the most conservative dive computer.

5. If the dive computer fails at any time during the dive, the dive must be terminated and appropriate surfacing procedures should be initiated immediately.

6. A diver should not dive for 18 hours before activating a dive computer to use it to control their diving.

7. Once the dive computer is in use, it must not be switched off until it indicates complete out gassing has occurred or 18 hours have elapsed, whichever comes-first.

8. When using a dive computer, non emergency ascents are to be at a rate specified for the make and model of dive computer being used.

10. Whenever practical, divers using a dive computer should make a stop between 10 and 30 feet for 5 minutes, especially for dives below 60 fsw.

11. Multiple deep dives require special consideration.

APPENDIX 9
AAUS STATISTICS COLLECTION CRITERIA AND DEFINITIONS

COLLECTION CRITERIA:

The "Dive Time in Minutes", The Number of Dives Logged", and the "Number of Divers Logging Dives" will be collected for the following categories.

- Dive Classification
- Breathing Gas
- Diving Mode
- Decompression Planning and Calculation Method
- Depth Ranges
- Specialized Environments
- Incident Types

Dive Time in Minutes is defined as the surface to surface time including any safety or required decompression stops.

A Dive is defined as a descent into water, an underwater diving activity utilizing compressed gas, an ascent/return to the surface, and a surface interval of greater than 10 minutes.

Dives will not be differentiated as openwater or confined water dives. But openwater and confined water dives will be logged and submitted for AAUS statistics classified as either scientific or training/proficiency.

A "Diver Logging a Dive" is defined as a person who is diving under the auspices of your scientific diving organization. Dives logged by divers from another AAUS Organization will be reported with the divers home organization. Only a diver who has actually logged a dive during the reporting period is counted under this category.

Incident(s) occurring during the collection cycle. Only incidents occurring during, or resulting from, a dive where the diver is breathing a compressed gas will be submitted to AAUS.

DEFINITIONS:

Dive Classification:

- Scientific Dives: Dives that meet the scientific diving exemption as defined in 29 CFR 1910.402. Diving tasks traditionally associated with a specific scientific discipline are considered a scientific dive. Construction and trouble-shooting tasks traditionally associated with commercial diving are not considered a scientific dive.
- Training and Proficiency Dives: Dives performed as part of a scientific diver training program, or dives performed in maintenance of a scientific diving certification/authorization.

Breathing Gas:

- Air: Dives where the bottom gas used for the dive is air.
- Nitrox: Dives where the bottom gas used for the dive is a combination of nitrogen and oxygen other than air.
- Mixed Gas: Dives where the bottom gas used for the dive is a combination of oxygen, nitrogen, and helium (or other "exotic" gas), or any other breathing gas combination not classified as air or nitrox.

Diving Mode:

- Open Circuit Scuba: Dives where the breathing gas is inhaled from a self contained underwater breathing apparatus and all of the exhaled gas leaves the breathing loop.
- Surface Supplied: Dives where the breathing gas is supplied from the surface by means of a pressurized umbilical hose. The umbilical generally consists of a gas supply hose, strength member, pneumofathometer hose, and communication line. The umbilical supplies a helmet or full-face mask. The diver may rely on the tender at the surface to keep up with the divers' depth, time and diving profile.
- Hookah: While similar to Surface Supplied in that the breathing gas is supplied from the surface by means of a pressurized hose, the supply hose does not require a strength member, pneumofathometer hose, or communication line. Hookah equipment may be as simple as a long hose attached to a standard scuba cylinder supplying a standard scuba second stage. The diver is responsible for the monitoring his/her own depth, time, and diving profile.
- Rebreathers: Dives where the breathing gas is repeatedly recycled in the breathing loop. The breathing loop may be fully closed or semi-closed. Note: A rebreather dive ending in an open circuit bailout is still logged as a rebreather dive.

Decompression Planning and Calculation Method:

- Dive Tables
- Dive Computer
- PC Based Decompression Software

Depth Ranges:

Depth ranges for sorting logged dives are 0-30, 31-60, 61-100, 101-130, 131-150, 151-190, and 191->. Depths are in feet seawater. A dive is logged to the maximum depth reached during the dive. Note: Only "The Number of Dives Logged" and "The Number of Divers Logging Dives" will be collected for this category.

Specialized Environments:

- Required Decompression: Any dive where the diver exceeds the no-decompression limit of the decompression planning method being employed.
- Overhead Environments: Any dive where the diver does not have direct access to the surface due to a physical obstruction.
- Blue Water Diving: Openwater diving where the bottom is generally greater than 200 feet deep and requiring the use of multiple-tethered diving techniques.
- Ice and Polar Diving: Any dive conducted under ice or in polar conditions. Note: An Ice Dive would also be classified as an Overhead Environment dive.
- Saturation Diving: Excursion dives conducted as part of a saturation mission are to be logged by "classification", "mode", "gas", etc. The "surface" for these excursions is defined as leaving and surfacing within the Habitat. Time spent within the Habitat or chamber shall not be logged by AAUS.
- Aquarium: An aquarium is a shallow, confined body of water, which is operated by or under the control of an institution and is used for the purposes of specimen exhibit, education, husbandry, or research. (Not a swimming pool)

Incident Types:

- Hyperbaric: Decompression Sickness, AGE, or other barotrauma requiring recompression therapy.
- Barotrauma: Barotrauma requiring medical attention from a physician or medical facility, but not requiring recompression therapy.
- Injury: Any non-barotrauma injury occurring during a dive that requires medical attention from a physician or medical facility.
- Illness: Any illness requiring medical attention that can be attributed to diving.
- Near Drowning/ Hypoxia: An incident where a person asphyxiates to the minimum point of unconsciousness during a dive involving a compressed gas. But the person recovers.
- Hyperoxic/Oxygen Toxicity: An incident that can be attributed to the diver being exposed to too high a partial pressure of oxygen.
- Hypercapnea: An incident that can be attributed to the diver being exposed to an excess of carbon dioxide.
- Fatality: Any death accruing during a dive or resulting from the diving exposure.
- Other: An incident that does not fit one of the listed incident types

Incident Classification Rating Scale:

- Minor: Injuries that the OM considers being minor in nature. Examples of this classification of incident would include, but not be limited to:
    - Mask squeeze that produced discoloration of the eyes.
    - Lacerations requiring medical attention but not involving moderate or severe bleeding.
    - Other injuries that would not be expected to produce long term adverse effects on the diver’s health or diving status.
- Moderate: Injuries that the OM considers being moderate in nature. Examples of this classification would include, but not be limited to:
    - DCS symptoms that resolved with the administration of oxygen, hyperbaric treatment given as a precaution.
    - DCS symptoms resolved with the first hyperbaric treatment.
    - Broken bones.
    - Torn ligaments or cartilage.
    - Concussion.
    - Ear barotrauma requiring surgical repair.
- Serious: Injuries that the OM considers being serious in nature. Examples of this classification would include, but not be limited to:
    - Arterial Gas Embolism.
    - DCS symptoms requiring multiple hyperbaric treatment.
    - Near drowning.
    - Oxygen Toxicity.
    - Hypercapnea.
    - Spinal injuries.
    - Heart attack.
    - Fatality.

CRFM

The CRFM is an inter-governmental organisation whose mission is to "Promote and facilitate the responsible utilisation of the region's fisheries and other aquatic resources for the economic and social benefits of the current and future population of the region". The CRFM consists of three bodies – the Ministerial Council, the Caribbean Fisheries Forum and the CRFM Secretariat.

CRFM members are Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago and the Turks and Caicos Islands.

CRFM

Caribbean Regional Fisheries Mechanism

www.crfm.int