# It Takes A Village

## Billfish Enthusiasts Worldwide Unite for Scientific Research

Photo by Stuart Simpson

VIMS | William & Mary
Virginia Institute of Marine Science

The University of Queensland
Australia

The International Game Fish Association

Gamefishing Association Australia

African Billfish Foundation

Photo by Roy Bealey

Since 2013, a number of anglers, scientists, conservation groups, and management agencies have worked together in a global effort to advance scientific research on istiophorid billfishes (marlins, spearfishes, and sailfish). These research efforts focused on addressing key knowledge gaps challenging the management and conservation of billfishes, including understanding how many populations exist in a given region, whether these populations interact, and if certain populations should be prioritized for conservation and management. Results from this work provide new insights for improving conservation and management efforts for billfish species worldwide, and also illustrate the importance of multi-sector collaborations in scientific research.

## Global effort for billfish research

Though their impressive size and spectacular fight displays make billfish premier sport species, **the wide-ranging and highly mobile nature of these fish present unique challenges for scientific research**. Routinely capturing and sampling large numbers of billfish is difficult due to the elusive nature of these species, and as a result **information necessary for the development of scientifically informed conservation and management strategies often lags behind** that of other more commonly encountered fishes.

## The species, people, and questions

Though the basic biology of all billfish species is poorly understood, research efforts described here focus on three species in particular: **black marlin (*Istiompax indica*), white marlin (*Kajikia albida*), and striped marlin (*Kajikia audax*).** These species are overharvested or experiencing unsustainable levels of fishing effort in at least a portion of their distributional ranges. Targeted management plans that consider the biological characteristics of distinct populations will improve the effectiveness of recovery efforts, **but are currently unachievable due to limited information on the number and spatial extent of populations present in a given geographic region.**


Photo by David Granville

**Figure 1. Collecting black marlin fin clips for genetic analysis.**

To address these knowledge gaps, Dr. Nadya Mamoozadeh of the Virginia Institute of Marine Science (Gloucester Point, Virginia, United States) and Dr. Sam Williams of the University of Queensland (St. Lucia, Queensland, Australia) worked to initiate **scientific research projects focused on using newly developed genetic methods to resolve genetically distinct populations of black marlin, white marlin, and striped marlin**. A primary goal of these projects was to provide information critical for improving conservation and management efforts for these species.

## Spreading the word

To accomplish this research, non-lethal tissue samples from billfishes distributed across the Atlantic, Pacific, and Indian oceans were required. **Anglers, scientists, conservation groups, and resource managers from across the globe were enlisted to help with this massive effort.** Angler networks through the **African Billfish Foundation** and **International Game Fish Association** (coordinated by Mr. Roy Bealey and Mr. Jason Schratweiser, respectively) were particularly supportive of this work. Hundreds of sampling kits were shipped worldwide, eventually forming a **global sampling network of anglers representing 29 countries and five continents.** The research described here would not have been possible without the many individuals who participated in this network, and the purpose of this article is to share results of this collaborative effort.

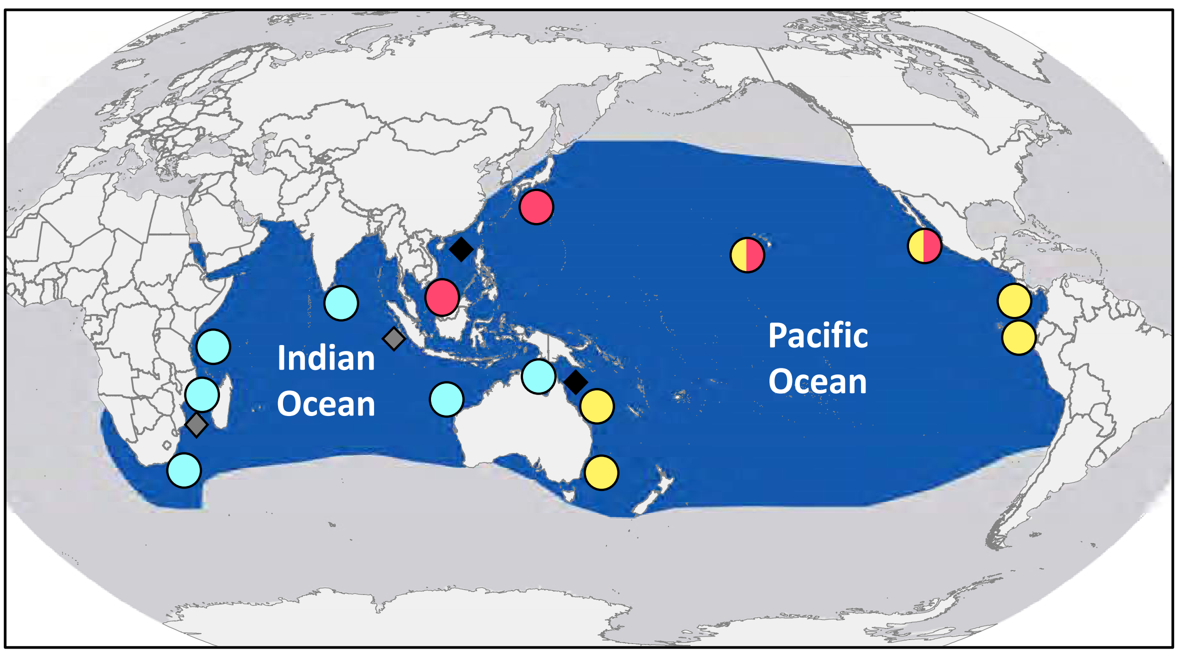
# Black marlin (*Istiompax indica*)

Black marlin has long been important to recreational fisheries across the Indo-Pacific, but harvest of this species in commercial and artisanal fisheries has increased in recent years. As a result, **some stocks of black marlin are now considered overfished and experiencing unsustainable levels of fishing effort**.

## How many populations are there?

Comparisons of DNA from black marlin sampled across the Indo-Pacific reveal that **this species represents a single population in the Indian Ocean** (Figure 2). This result is consistent with tagging data that show movements of black marlin between geographically distant regions of the Indian Ocean. In comparison, **black marlin in the Pacific Ocean comprise two genetically distinct populations** (Figure 2). One of these populations spans the South Pacific, representing a high level of genetic connectivity between black marlin off eastern Australia and the Pacific coasts of Central and South America. A second Pacific population corresponds with black marlin from the western North Pacific (in the Gulf of Thailand and South China Sea). Interestingly, **black marlin sampled off Hawaii and Baja California include fish from both Pacific Ocean populations**. This finding suggests that Pacific populations mix on shared feeding grounds in the central Pacific, then return to previously confirmed spawning grounds in the South China Sea (South Pacific population) or Great Barrier Reef (North Pacific population; Figure 2). These genetic findings are consistent with movement patterns inferred from conventional and satellite tags deployed on black marlin in the Pacific Ocean.

**Figure 2. Map showing spatial distribution of black marlin (blue) and sampling locations of fish analyzed in this study (circles). Sampling locations are colored to show the locations of three genetically distinct populations. ♦ = previously confirmed spawning location, ♦ = possible additional spawning location.**




## What else did we find?

Thanks to the help of anglers in Mozambique, several recent observations suggest the **possibility of black marlin spawning off the Bazaruto Islands in the western Indian Ocean**. Additional observations indicate that **spawning may also occur off Sumatra in the eastern Indian Ocean**. Though these findings are preliminary, they may provide new insights into locations important for black marlin spawning.

## What does this mean for management?

**Management measures that regulate regional catches of black marlin in the Indo-Pacific are presently lacking**. The genetic results described here provide information for developing **population-specific assessment and management initiatives for black marlin**. Such initiatives are especially important for promoting the recovery of overfished stocks, including by determining harvest levels suitable for each stock.

# White marlin (*Kajikia albida*)

White marlin is a popular target of recreational fisheries Atlantic-wide; however, this species has been considered **overfished for over two decades**. One factor which may be limiting the effectiveness of recovery efforts for white marlin is a **poor understanding of population structure**. Early comparisons of DNA failed to detect genetically distinct populations of white marlin in the Atlantic Ocean, but a study completed in 2006 suggests the possibility of populations corresponding with the North Atlantic and South Atlantic oceans. Additionally, recent reports from white marlin tagged with pop-up satellite archival tags for a full year demonstrate movements confined to specific regions of the Atlantic Ocean, including time spent on previously confirmed spawning grounds during the spawning season (Figure 3). Collectively, this information suggests that population structuring may be possible for white marlin.

## How many populations are there?

Genetic analysis of white marlin sampled across the Atlantic Ocean (Figure 4) reveal a **lack of genetic differences among sampling locations, suggesting the presence of a single ocean-wide population**. However, it is important to recognize that **these genetic results can reflect more than one biological scenario**. For example, it is possible that biologically distinct populations of white marlin exist, but a small number of fish that stray and reproduce in non-natal populations provide enough genetic connectivity to make biologically distinct populations appear genetically similar. Therefore, **future studies that use non-genetic approaches to study white marlin population structure are necessary for informing the biological context of these genetic results**. Ocean-wide electronic tagging efforts that use deployment periods of at least a year will be especially helpful for understanding movements on annual timescales.

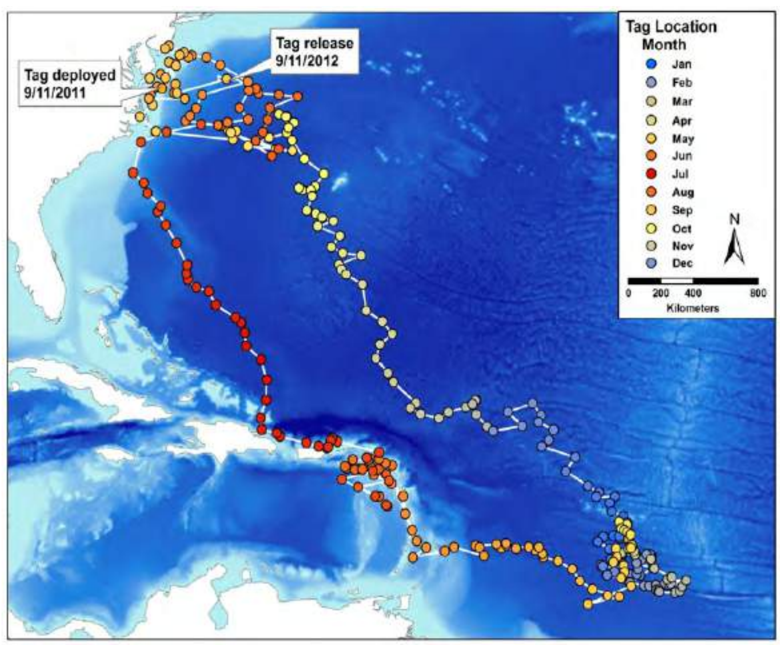



**Figure 3. 365-day geolocation track for a satellite tag deployed on a white marlin off the mid-Atlantic United States in September 2012. Points represent estimated locations and are colored by month. Figure from Emily Loose.**

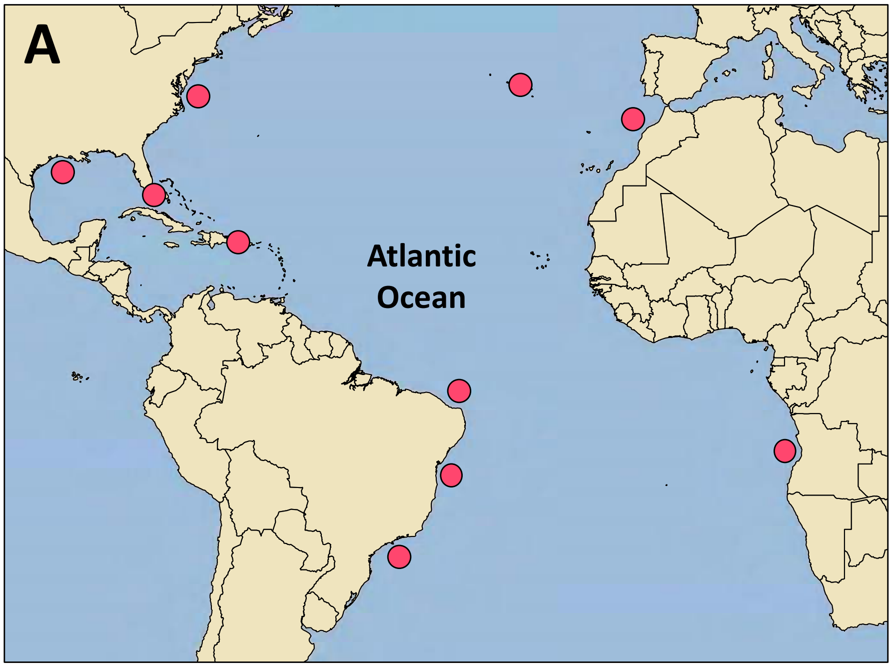




**Figure 4. A: Map of white marlin sampling locations in the Atlantic Ocean (circles). Genetic differences were not observed among sampling sites. B: Tissue sampling prior to release.**

## What does this mean for management?

**The genetic results described here are consistent with the assessment and management of white marlin as a single Atlantic-wide stock**. Importantly, this single stock assessment and management model was adopted by fisheries managers in 2001, and still appears to be in appropriate use.

# Striped marlin (*Kajikia audax*)

Striped marlin (Figure 5) is recreationally targeted throughout the Indo-Pacific, and is also harvested in commercial and artisanal fisheries in some regions. **In the Pacific Ocean, three stocks of striped marlin are currently recognized for assessment and management purposes; however, these stocks do not correspond with the genetically distinct populations identified in previous studies**. **In the Indian Ocean, stock structure for striped marlin is entirely unknown**. This lack of information is especially problematic because striped marlin is heavily overfished and experiencing excessive fishing effort in the Indian Ocean. **Developing population-specific management measures is an important first step in promoting the recovery of overfished stocks**, but this requires an understanding of population structure throughout the species range.


**Figure 5. A tagged striped marlin ready for sampling prior to release.**

## How many populations are there?

Genetic analysis of striped marlin sampled across the Indo-Pacific (Figure 6) reveals the presence of **five genetically distinct populations**. Two of these populations span regions of the North Pacific Ocean, a third populations corresponds with the eastern central Pacific Ocean, and a fourth population is located in the western Indian Ocean (Figure 6). Striped marlin from Oceania (including fish sampled from waters off western Australia, eastern Australia, and New Zealand) represent a fifth population, reflecting a **high degree of connectivity between striped marlin from the eastern Indian Ocean and western South Pacific Ocean**. Importantly, the western Indian Ocean populations displays lower genetic diversity and a greater degree of isolation relative to other stocks, signalling that this population should be prioritized for conservation and management.

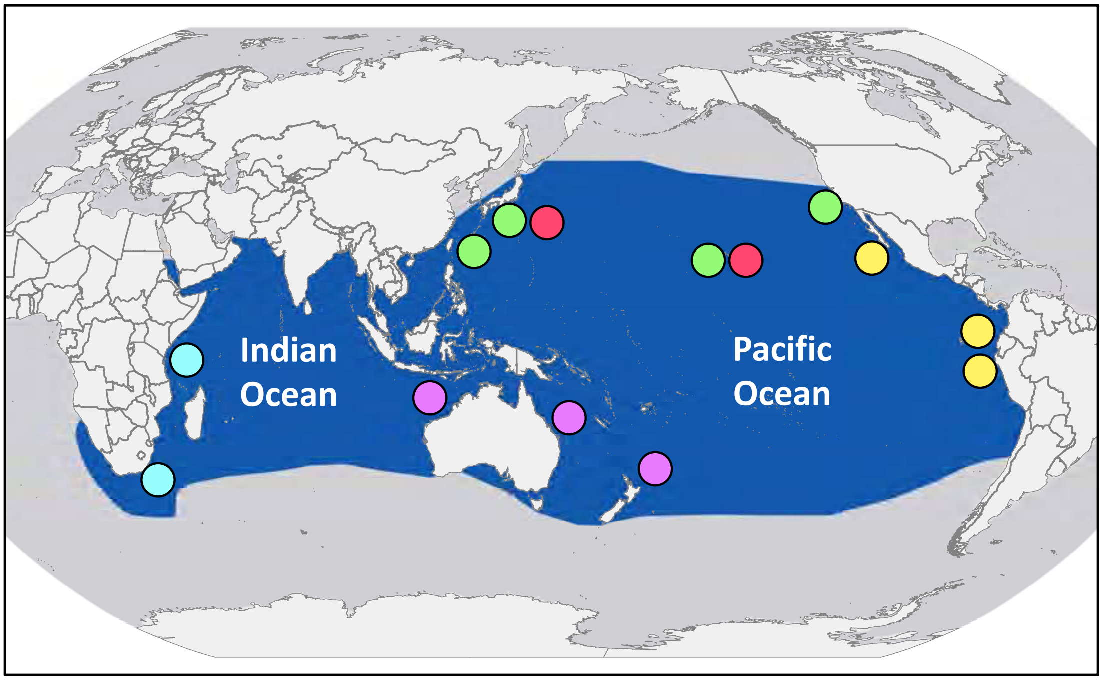



**Figure 6. Map showing spatial distribution of striped marlin (blue) and sampling locations of fish analyzed in this study (circles). Sampling locations are colored to show the locations of five genetically distinct populations.**

## What does this mean for management?

**These results demonstrate a need for redefining the stocks currently recognized by fisheries managers in the Indo-Pacific** to better reflect genetically distinct populations of striped marlin. This improvement will increase the effectiveness of management initiatives, and enable the conservation of population-specific genetic diversity important for the long-term persistence of striped marlin.

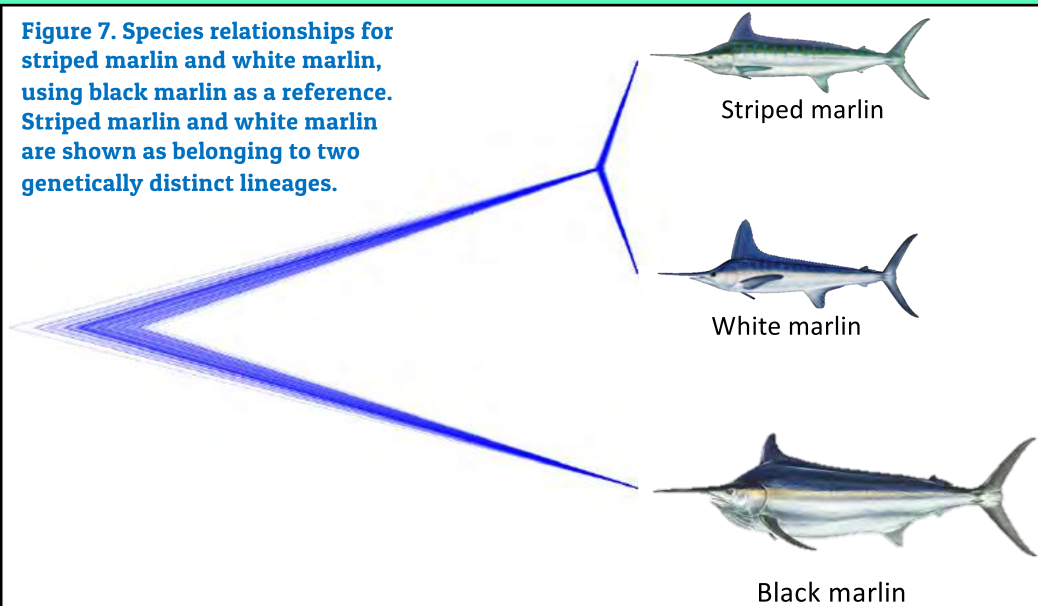
# Striped marlin and white marlin

**For decades, there has been much debate as to whether striped marlin and white marlin represent two distinct species**. Given morphological similarities between striped marlin and white marlin, **these species are primarily distinguished based on whether a fish was captured in the Atlantic (white marlin) or Indo-Pacific (striped marlin). But what happens in regions where the spatial distributions of these species overlap?** In some years, water temperatures off South Africa are suitable for both striped marlin and white marlin, and a handful of reports document the occasional presence of both species in this region. Adding even more intrigue, **previous genetic studies have been unsuccessful in resolving striped marlin and white marlin as genetically distinct.**

## How many species are there?

To infer whether striped marlin and white marlin represent distinct evolutionary lineages, DNA was compared among fish sampled from the Atlantic, Pacific, and Indian oceans. Results from these comparisons **clearly indicate that striped marlin and white marlin are genetically distinct** (Figure 7). **However, a small number of fish contain genetic signatures from both species. One possible explanation for this observation is the recent occurrence of a common ancestor to striped marlin and white marlin.**

**Figure 7. Species relationships for striped marlin and white marlin, using black marlin as a reference. Striped marlin and white marlin are shown as belonging to two genetically distinct lineages.**

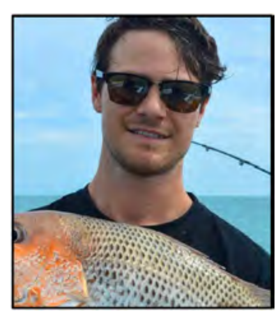



## Why is this important?

From a management perspective, **a clear understanding of what represents a species is necessary for conserving genetic variation unique to distinct evolutionary lineages**. Future studies to determine whether the small number of fish displaying ancestry from both striped marlin and white marlin reflect present day interactions between these species or a signature from the past will require analyses of additional tissues from fish sampled off South Africa and in neighboring waters.

# A Global Network of Volunteers

**This research was made possible thanks to a global network of anglers, scientists, conservation groups, and fisheries managers who collected several hundred non-lethal fin clips from billfishes across the Atlantic, Pacific, and Indian oceans.** These efforts provide an excellent example of **community-based science**, and highlight the **strong conservation ethic of the recreational sportfishing community**. Special thanks goes to the **International Game Fish Association** and its global network of representatives, the **Game Fishing Association Australia**, and the **African Billfish Foundation**.



**Thanks to everyone that contributed to our work! (Dr. Nadya Mamoozadeh, left; Dr. Sam Williams, right)**