BRIEF SYNOPSIS OF THE BIOLOGY OF THE BLUE MARLIN *(MAKAIRA NIGRI CANS)*, WITH REFERENCE TO THE INDIAN OCEAN.

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Taxonomy

The blue marlin is a member of the family Istiophoridae and one of two members of the genus *Makaira*. Note comments on the closeness of this relationshiip in the working paper on black marlin, by the author.
The blue marlin is identified by its relatively high and pointed dorsal fin (usually about two-thirds the maximum body depth), its folding pectoral fins and its large anal fin. Other features are its relatively short lower jaw, and its gun-metal blue/grey colour after death. Blue marlin occur in all three major oceans. The Indo-Pacific variety has always been regarded as a single species, but blue marlin in the Atlantic have been considered by some scientists to be separate species. The only feature which has been described as being different between the two is the pattern of the lateral line. On the surface, the lateral line of blue marlin is virtually invisible, but forms a 'chicken-wire' like pattern on the underside of the skin. According to Japanese biologist Izumi Nakamura, the 'mesh' of the 'chicken-wire' is much finer in the Atlantic variety compared with the Pacific variety. Recent genetic have failed to verify that speciation has occurred between the Indo-Pacific and the Atlantic, and most workers now consider the blue marlin to be a single, cosmopolitan species, *Makaira nigricans*. Nevertheless, *Makaira mazara* is still used by some authors for the Atlantic blue marlin.

Distribution

The distribution of blue marlin is circumtropical, extending to about 45° latitude in both hemispheres. Blue marlin are the most tropical of the marlins, as well as the most oceanic. They are normally associated with open ocean or island habitats throughout their range, not usually being considered a billfish which occurs over the continental shelf (On Japanese maps, the distribution of blue marlin is shown as ending at the edge of the continental shelf of all land masses). The area of highest catch rates lies between 15°N and 25°S. In the Indian ocean, they are distributed to approximately 45°S in the western Indian Ocean and to 30°S in the eastern Indian Ocean. While blue marlin concentrate year-round in tropical waters, part of the population (usually females) undertake large seasonal movements away from the equatorial waters to about 30°S. Seasonal concentrations of blue marlin in Australian waters are not, however, as well defined as those for black or striped marlin. Highest catch rates in both the Coral Sea and off northwest Australia occur between January and March. Like black marlin, tagging studies of blue marlin have demonstrated long distance movements and homing behaviour with fish being recaptured at the site of tagging at yearly intervals (Figure 5). As well, tagged blue marlin are often captured remote from the tagging site at half yearly intervals. Major seasonal concentrations of blue marlin occur around the Laccadive and Maldive Islands off the southwest coast of India (December-August) and in the general area east of Mauritius in the southwest Indian Ocean (December to February). They occur year-round in the Eastern Indian Ocean between northwest Australia and Java and the Lesser Sunda Islands. Maximum concentration in the area is during the northeast monsoon from November to April. As in the Coral Sea, maximum catch rates of blue marlin off Western Australia tend to occur further offshore (away from the continental shelf) than for black marlin.

Movements/Stock Structure

Most tagging of blue marlin has taken place in the Atlantic ocean, mainly from the eastern United States and in the Caribbean. Over 30 years, over 20,000 blue marlin have been tagged by recreational anglers in the region, and hundreds have been recaptured. Movements have been extensive, with several trans Atlantic crossings being recorded. The most startling recapture though was a fish tagged off South Carolina and recaptured three years later near Mauritius in the Indian Ocean — the first proven movement between two oceans for any fish (Atlantic to Indian).

In the Pacific, recreational tagging off southeastern United States and Hawaii has also revealed some very extensive movements. The most notable of these was a blue marlin tagged off Hawaii which was recaptured near Taiwan. Off Australia, even though about 700 blue marlin have been tagged and released, there have only been three recaptures to date. Again, one of these was spectacular. This was a blue marlin tagged off Sydney and recaptured 18 months later by a Japanese longliner 300 n. miles south of Sri Lanka — the second inter oceanic movement of a fish (Pacific to Indian) and again, a blue marlin.

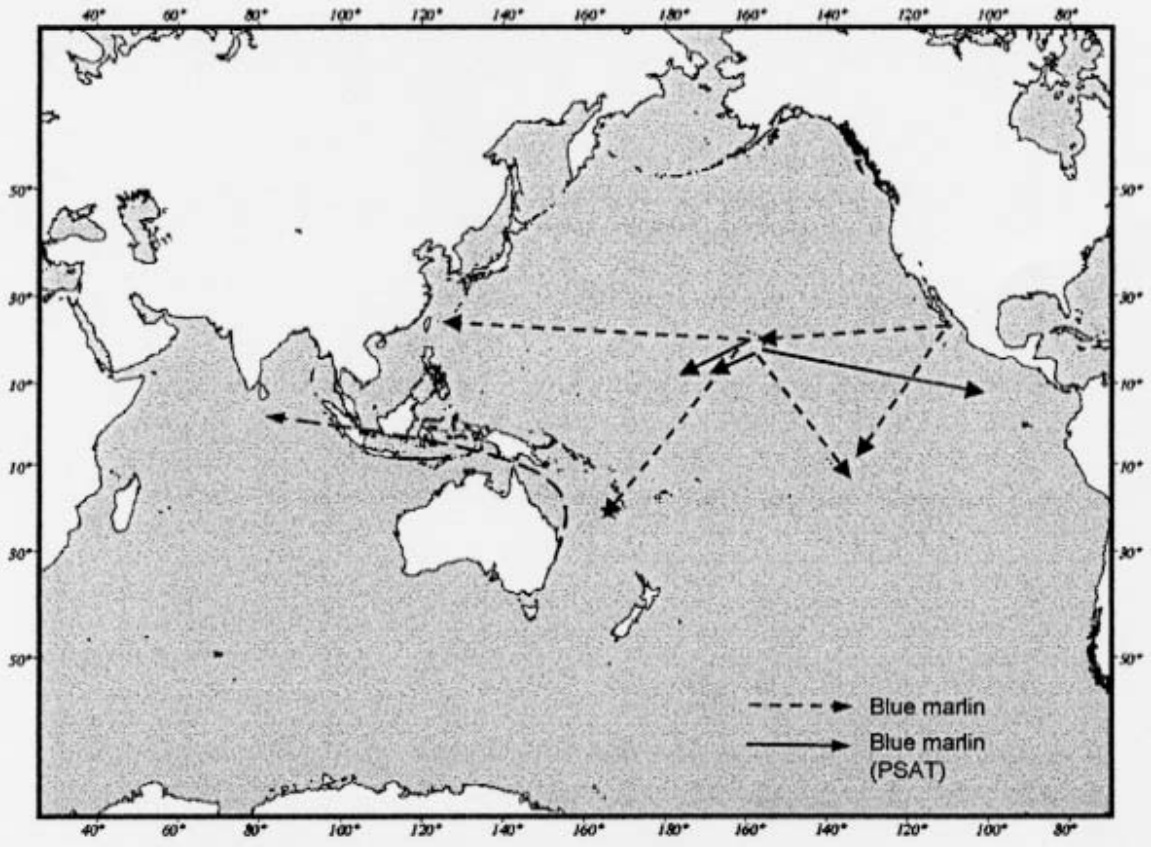

Figure 1. The tag and release and recapture positions of selected blue marlin tagged by recreational anglers in the Pacific Ocean. Three blue marlin movements in the figure are based on data collected from 'pop-up satellite tags' (PSATs) deployed on blue marlin captured in Hawaiian waters by Dr. Barbara Block.

The population structure of blue marlin has been investigated using a variety of molecular genetic techniques which survey molecular markers with different evolutionary rates and modes of inheritance. These include allozyme analysis (Shaklee et al. 1983, Buonaccorsi et al. 1999), restriction fragment length polymorphism (RFLP) analysis of mitochondrial (mt)DNA (Graves and McDowall 1995), sequence analysis of mtDNA (Finnerty and Block 1992)

RFLP analysis of anonymous single copy nuclear (ascn) DNA (Buonaccorsi et al. 1999), and microsatellite DNA analysis (Buonaccorsi and Graves 2000; Buonaccorsi et al., submitted). In general, as resolution of genetic techniques has increased, more and more genetic variation has been found within the range of blue marlin. Polymorphic allozyme and ascnDNA loci are typically diallelic (two alleles segregating at a locus), while mtDNA and microsatellite loci may have 40 or more alleles. With increasing variation, larger sample sizes are required to reflect the genetic composition at a location. All of the above molecular techniques have revealed significant genetic divergence between samples of blue marlin from the Atlantic and Pacific oceans. None, however, has demonstrated significant partitioning of genetic variation among samples taken from locations within the Pacific Ocean. In addition, no significant genetic differences have been found among samples of blue marlin taken from the same location in different years. This has allowed investigators to pool samples from given locations taken at different times to increase the power of subsequent geographic analyses. Nevertheless, analyses of relatively large samples of Pacific blue marlin from Hawaii, Mexico and Australia have been unable to discriminate structuring using any of the above molecular methods. Thus the null hypothesis, that blue marlin within the Pacific Ocean comprise a single genetic stock, cannot be disproved. This result indicates that there is at least sufficient gene flow among geographically distant locations of blue marlin to prevent the accumulation of significant genetic differences. This could be as little as a few individuals per generation, or it could be considerably larger. Such interchange is not inconsistent with the results of tagging studies (above) indicating that blue marlin are capable of extensive movements within the Pacific Ocean and even into the Indian Ocean. The extent of any linkage between the Indian Ocean and Pacific Ocean populations of blue marlin remains unknown. The shallower waters of the Indo/Malay archipelagos are often considered to be a barrier to movements between these two oceans. Nevertheless, as noted, the only recapture to date of a blue marlin tagged off eastern Australia (Port Stephens) is for a fish caught off Sri Lanka. The possibility that this fish moved around southern Australia cannot be ruled out.

Size and Growth

There have been several studies of the growth rates of blue marlin. One study on Hawaiian blue marlin estimated the following weights at age: For males, 52kg at age 6 years, 68-71kg at 7-8 years, 82kg at 9 years and 97-114kg at 11-12 years. Females attain a weight of 135-147kg at age 8, 209-229kg at age 13-15, 286kg at age 16 and 337kg at age 17. There is, however, an apparent very high variability in size at age; a 175kg female may range from 6 to 17 years of age. It should be stressed that this study, and others, relied on assuming that external ridges on the tiny otoliths of blue marlin were formed annually. This relationship has not, however, been validated. The ages at size quoted, in fact, do seem to be quite high, since counts of presumed daily rings on small Atlantic blue marlin indicate that the early growth rate of blue marlin is very rapid, reaching 30 kg in less than one year. Life expectancy may be up to 21 years for males and 28 years for females, although again, such estimates need to be based on validated ageing. As for black marlin, blue marlin also show a strong sexual dimorphism with males rarely exceeding 180kg.

The size range noted for blue marlin caught in the Indian ocean by Japanese longliners in the 1960s ranged between 121 to about 260cm body length. In all areas except off western Australia, the modes fell between 161 and 190cm. The smallest size mode was found in the Arabian Sea (161-170cm), the central

Australia shows a mode at 171-180cm. The largest modal size (201-231cm) was found off western Australia south of 20°S. Fish of this size weigh between 105kg and 165kg.

The two largest verified Istiophorid billfish ever weighed were blue marlin, both caught off Hawaii. The largest weighed 1,805 pounds (820 kg) and was landed by a party of novice anglers aboard a charter boat off Honolulu. An undated photo of this fish depicts an apparently grossly obese fish. The second heaviest billfish was also a blue marlin which weighed 1,656 pounds (753 kg) and was caught off Kona Hawaii in 1984. (Due to technical rule violations, neither of these fish appear in the records of the International Game Fish Association). There are many stories of blue marlin which are supposed to have weighed in excess of 2,000 pounds (even as high as 2,600 pounds) being caught by commercial longline vessels, but even with concerted efforts, it has not been possible to verify such claims.

Reproduction

The main recreational fishing areas for blue marlin around the world tend to be near islands. These include Hawaii in the Pacific, Mauritius in the Indian, the Caribbean islands in the Atlantic, as well as many smaller islands in each ocean. These islands are all tropical to subtropical, and many appear to be areas of seasonal spawning for blue marlin.

A long term study in Hawaii found that nearly 80% of the blue marlin landed during a large summer tournament were males, mostly less than 90 kg in size. The female fish covered a much greater size range, from as small as 22 kg to over 500 kg. Examination of the gonads of these fish showed that most males were running ripe, while females contained mostly highly developed ovaries, many of which were also running ripe. This study clearly showed that spawning of blue marlin, at least in the sub-tropical latitude of Hawaii, is highly seasonal and predictable. Similar results have been obtained from Mauritius indicating that blue marlin are able to locate remote islands as the spawning season approaches. There have been no studies of reproductive activity of blue marlin in Australian waters. Whilst the occurrence of larvae in the Coral Sea indicates that some spawning does occur off the east coast of Australia, its extent and significance remain unknown.

Larval occurrence is the principle reason for the belief that at least some spawning occurs year-round in equatorial waters (10°S-20°N) and during respective summer periods in the southern and northern hemispheres (to 30°S and 20°N). A similar pattern is assumed in the Indian Ocean and, again, whilst large numbers of blue marlin larvae have been collected in the area bounded by north-west Australia, Indonesia and the central Indian Ocean between October and March, the significance of this area as a spawning ground remains unknown. Observations based on ripe fish caught in Hawaiian waters indicate that blue marlin reach maturity around 31kg for males and 80kg for females.

Blue marlin apparently make extensive excursions away from the tropics into quite temperate regions, at least along the eastern seaboards of Australia and

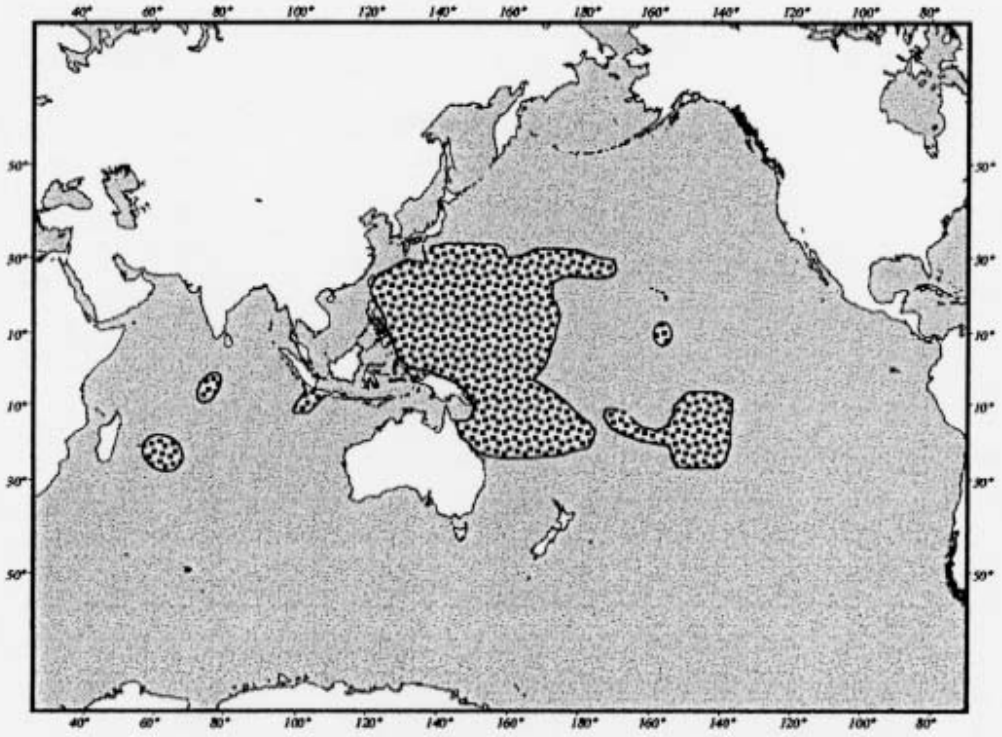

Figure 2. Presumed spawning grounds for blue marlin based on collections of larvae and adult fish in spawning condition.

the United States. Interestingly, the fish which take part in this movement away from the tropics tend to be adult females which are in non-spawning condition. Off the eastern Australian coast, specifically, off New South Wales, the sex ratio of blue marlin caught by gamefish anglers for the past decade is highly skewed towards females. Such skewed sex ratios have been observed before in billfish catches by Japanese scientists, and it is clear that the sexes do separate in many cases. This generally occurs outside the spawning season, or away from spawning grounds, so it is likely that the blue marlin which find their way along the temperate shelf edges of continents are females taking the opportunity to feed between spawning seasons. It seems that male fish rarely undertake such movements.

Behaviour

The vertical behaviour of blue marlin has been studied by means of ultrasonic telemetry. Tracking of six blue marlin off Kona for up to 48 hours, showed that there was a noticeable increase in erratic activity for the first few hours after release, after which time the fish tended to undertake quite similar behaviour patterns. Cruising speed averaged about two knots, and the great majority of time was spent within the mixed layer above a depth of about 80 m. Blue marlin apparently treat the thermocline as if it was a semi physical barrier. Thus, their vertical movements oscillate between the surface and the thermocline, with occasional but brief forays into deeper, colder water.

One of the interesting finding which emerged from the early sonic tracking work was that the depth blue marlin swim is strongly influenced by the prevailing light. During daylight hours, fish tend to swim deeper, often near

the thermocline, whereas at sunset, behaviour changes and they become much more surface oriented during the night. It is however whether feeding still takes place at night. Tracking of blue marlin over longer periods (up to 4 days) indicated a tendency for fish to keep moving away from their release points, but parallel to the coast, throughout the tracking period. One such fish moved a total distance of 160 km in 4 days. Recently, 9 blue marlin were tagged with pop-up satellite tags off the Bahamas in the Caribbean. The tags were all timed to release from the fish after 5 days. Eight did so, and demonstrated a mean displacement of 91 nautical miles away from the release locations in that time.