Occurrence and Lifestyles of Bluefin Tuna in the Gulf of Maine: Implications for MPA s

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The Atlantic bluefin tuna, *Thunnus thynnus*, is a highly mobile, valuable pelagic fish that routinely crosses high seas jurisdictional boundaries. Together with other tunas, pelagic sharks, and billfishes, bluefin tuna have been under international management by ICCAT (International Commission for the Conservation of Atlantic Tunas) since 1981. This species, partitioned into two separate Atlantic stocks divided at 45 deg W, has proven extremely difficult to manage, and lack of information on its most basic biological attributes has contributed to uncertainty in its population status. Although Atlantic-wide TAC s are in place, intense fishing pressure, especially in the eastern management zone, threatens its recovery. Before managers can optimize ecosystem-based and precautionary approaches for this top trophic level consumer, information is needed on bluefin abundance, distribution, and linkage with prey. These unknowns contribute to the complexity of issues facing protection of highly migratory species within a Marine Protected Areas framework.

In 1993, the New England Aquarium undertook an aerial survey program to improve our understanding of the bluefin tuna s regional abundance and distribution in the Gulf of Maine. Annual fishery-linked spotter pilot surveys (1993-96) provided information on the spatial and temporal scales of school movements, behavior, and environmental associations. We then conducted hydro acoustic tracking studies to identify dynamic linkage of areas of surface abundance, and to document horizontal and vertical movement of bluefin schools. Two consistent patterns emerged: foraging with small daily displacements (e.g. < 20 km d^{-1}) and repetitive travel through the thermocline (0-220 m), and large displacements (e.g. 40 -78 km d^{-1}) with travel primarily in the surface layer (<12 m). We then integrated aerial survey data and sonic tracking results to construct individual based, 3-dimensional movement models in order to obtain residency indices and estimates of regional biomass. Through GIS, modeling, and feeding studies, we can now add prey base and location of persistent oceanfronts and productivity to examine relevant habitat attraction parameters.

As is the case with many other large pelagic species, bluefin tuna are seasonal residents in the Gulf of Maine. After intensive feeding in summer and fall, they undertake Atlantic-wide migrations to overwintering and spawning grounds, yet migration paths to the presumed spawning area remained in speculation. Since 1997, in a collaborative study between the USA, Canada and tuna fishermen, we deployed a total of 88 pop-up satellite tags on spawning size class bluefin tuna in the Gulf of Maine or adjacent areas.   These fishery-independent tags were scheduled to jettison from the fish after 5 - 12 months, and most, over the presumed spawning period. All successful tag releases reported from the north central Atlantic, each year ≥30% of the tagged bluefin were located east of the stock division line, and none were in known spawning areas when the tags jettisoned. New light archiving pop-up tags provided daily geolocation estimates and complete migration paths for 12 fish to date, demonstrating fairly long residencies

in the north central Atlantic. These results challenged basic assumptions about bluefin migration, and in particular, where and when spawning occurs, and the range and extent of mixing between east and west.

For highly migratory species whose movements are inherently complex and linked across spatial scales, MPA   s will need to be dynamically structured to protect migration paths, feeding and spawning areas. An adaptive approach that integrates near real time biological and remote sensing data and modeling simulations can identify and characterize bluefin habitats in the Gulf of Maine and beyond. In addition, the value of basic biological studies with research partnerships that include fishermen cannot be overstated, as in the case of bluefin tuna, they have led to the formation of relevant new paradigms in fisheries management.