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Bio-logging of marine migratory species in the law of the sea

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ABSTRACT

The use of advanced and emerging remote data-collection technologies, and in particular bio-logging of marine migratory species, raises fundamental questions about the scope of authority of coastal states to regulate marine scientific research in the waters under their jurisdiction. Bio-logging involves the attachment of devices to marine animals that collect and transmit data about their movements and aspects of the local marine environment, and is now routinely used by marine scientists to support conservation programs and augment oceanographic data collection. Tagged marine life, including seabirds, marine mammals, sea turtles and pelagic fishes, may interact unpredictably with the territorial seas and exclusive economic zones (EEZs) of numerous coastal states. This article explores the legal implications of bio-logging within the legal regime of marine scientific research in the law of the sea. Although bio-logging is a form of marine scientific research, when it is initiated outside a coastal state's jurisdiction it does not later fall within it, even if the tagged animals subsequently enters a coastal state's territorial sea or EEZ.

1. Introduction

Breakthroughs in technology that facilitate efforts by scientists to monitor the movements of marine migratory species and collect and transmit environmental data gives rise to new questions in the law of the sea [1]. The law of the sea recognizes the special importance of highly migratory species as critical shared resources, although this list is no longer comprehensive. (Appendix A1). Rules for deployment of research vessels and the conduct of traditional MSR are set forth in the United Nations Convention on the Law of the Sea (UNCLOS).[1] Coastal states have the right to regulate and authorize MSR in offshore areas under their sovereignty and jurisdiction, including a 12-nautical mile (nm) territorial sea and 200-nm EEZ. Unlike traditional MSR, coastal states lack authority to regulate marine animal bio-logging and tracking of species that may be found inside their territorial sea and EEZ when the research is initiated by scientists outside of these areas. Even though tracking and collection of data through devices on marine animals that have transited or at least partially inhabit a coastal state's territorial sea and EEZ might appear to implicate the sovereignty and jurisdiction of the coastal state, it does not because the marine species are autonomous and entirely independent of any human programming or control.

Coastal states have authority over marine scientific research (MSR) that is conducted in their territorial sea and exclusive economic zone (EEZ). Traditionally, MSR was done from a ship operating in the EEZ, and the presence of the ship in water under the sovereignty or jurisdiction of the coastal state required the consent of the coastal State. Bio-logging, however, is a new form of MSR that is not similarly constrained. Bio-logging permits the collection and use of data transmitted or retrieved from devices affixed to marine animals [2]. When the devices are attached to marine migratory species on the high seas or in any other area outside of the jurisdiction of a particular coastal state, and the animals subsequently migrate into the territorial sea or exclusive economic zone (EEZ) of that state, it is not entitled to require permission or withhold consent for the MSR even though the data were collected in areas under its sovereignty or jurisdiction.

Coastal states enjoy sovereignty over the territorial sea, although their authority is not unlimited. Ships of all states, for example, may exercise the right of innocent passage, and entry into the territorial sea in case of *force majeure* is lawful as well. Likewise, coastal states have sovereign rights and jurisdiction over the living and non-living resources in the EEZ, as well as jurisdiction over some types of vessel-source pollution. Similarly, in the EEZ, although the coastal state enjoys exclusive sovereign rights

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[1] *United Nations Convention on the Law of the Sea*, opened for signature 10 December 1982, 1833 UNTS 397, (entered into force 10 November 1994) (UNCLOS).

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"for the purpose of exploring and exploiting, conserving and managing" marine species, they do not claim exclusive ownership over migratory species, such as sea turtles, "at least not while they are swimming freely in their natural habitat – the oceans."[2] Furthermore, coastal states are presumed to authorize their consent for marine scientific research (MSR) in their EEZ, although they are entitled to withhold consent under some circumstances. Bio-logging and tracking of marine migratory species is a form of MSR, however, that bypasses the traditional method of marine science conducted from a dedicated research vessel, thereby complicating (or even erasing) the coastal state's exclusive authority to control it.

2. Bio-logging

Animal tagging and tracking with remote instruments – now often referred to as bio-logging – is one of the most efficient and accurate methods of assessing a species movement ecology, habitat-use and behavior [3]. Advances in very small, low power, microelectronics have generated a bevy of new monitoring devices that can be attached to marine animals in order to collect scientific data and transmit it remotely, often by satellite or other wireless technologies [3]. Data collected through these techniques generally includes information on the behavior and activities of tagged animals such as diving behavior, foraging movements and migration patterns [3]. In some cases these instruments can also provide data on the surrounding ocean, such as salinity, currents and temperature, providing details on the environment the animal is swimming through [2]. Several forms of bio-logging platforms are in use, and they can be separated out by their mode of data collection and recovery.

The simplest forms of bio-logging instruments emit a radio signal that is tracked via satellite [4] or VHF antenna [5] and animal locations are estimated via triangulation/Doppler-shift techniques [6]. Advanced forms of these platforms can relay dive information as well over radio frequencies. These devices are used on a variety of marine organisms; however, their use is restricted to animals that surface periodically or fly (e.g. marine turtles, seabirds, marine mammals and some large pelagic fishes) as radio signals are not propagated through the water. In contrast, many bio-logging platforms are archival, where data is collected (often including higher resolution location data derived from GPS systems) and stored onboard the devices and then downloaded/transmitted after the deployment finishes [6]. In some cases archival tags must be recovered (usually by tracking it with a co-located radio beacon as above) and the data downloaded manually. This can be accomplished if the platform is released from the animal at a certain time or, in the case of small animals, during a recapture period where the tag is removed during animal handling at a rookery or haulout [7]. In some cases, data can be collected over an extensive period of time and then transmitted when the tag is shed from the study animal [8], or it spends enough time onshore for data to be transmitted from the tag [9]. This is especially true for platforms developed for pelagic fishes that employ light-based geo-location techniques. These tags calculate positions of animals using ambient light levels and these data are transmitted to researchers via satellite relay when the tag is shed from the animal and floats to the surface [10]. In many cases real-time tracking is not possible with many archival bio-logging platforms.

[2] UNCLOS, art. 56 and *WTO Appellate Body Report on U.S. – Import Prohibition of Certain Shrimp and Shrimp Products*, WT/DS58/AB/R (October 12, 1998), para 133.

2.1. Bio-logging in marine science and conservation

The use of telemetry and bio-logging devices on all the major taxa of marine top predators, including fishes, marine reptiles, seabirds, and marine mammals, promotes novel marine scientific research without the need for expensive and conventional research cruises. The surge in demand for marine science data and the cost and challenge to secure ship time at sea has made governments and scientists seek alternatives to traditional approaches. In many cases, bio-logging is an attractive method for collection of biological and physical data [2].

Bio-logging is now playing an important role in the conservation of many highly mobile marine species and the habitats they rely on. This includes, amongst other things, providing data on the interactions of marine species with fisheries [11,12], identification of foraging regions and relationships with static and dynamic ocean features at various scales [13–15], and providing data critical for calculating more precise abundance estimates [16,17]. The utility of bio-logging for marine resource management is now widely accepted by marine ecologists and oceanographers [2].

UNCLOS obligates states to conserve wide-ranging and valuable species.[3] The use of bio-logging has particular salience for the management and conservation of threatened migratory species [18]. The Convention on Migratory Species (CMS), for example, has classified species that are in peril of extinction,[4] and identifies those subject to special protective measures.[5] The ability to effectively manage such species; however, is hampered by the requirement to undergo lengthy, expensive and sometimes unsuccessful administrative and logistical processes to obtain permission to conduct MSR in coastal state EEZs. Long-range migratory species may not only enter several countries EEZs individually and as a species, but do so in an unpredictable manner. The new modality of bio-logging improves our understanding of the life histories of migratory species and contributes to international management and conservation of them.

2.1.1. Jurisdictional complexity of bio-logging

A rapid survey of geospatial data in the OBIS SEAMAP[6] archive demonstrates the large number of EEZs that are crossed, entered, and transited by specific marine highly migratory species (Table 1). For example leatherback turtles, one of the most widely ranging marine turtle species, have been recorded in 67 coastal state EEZs. Humpback whales, a mammalian species that makes extensive yearly migrations from feeding to breeding grounds have been recorded in 57 coastal state EEZs. Atlantic Bluefin tuna are found in at least 17 different EEZs. Perhaps most importantly, the movements of these widely ranging marine species are defined by the unpredictable nature of individual behaviors and dynamic migration routes. These complexities are illustrated below using examples of telemetry data from across the major taxa studied through bio-logging techniques in marine systems.

The distribution and migration routes of many marine species are dynamic and unpredictable, varying among individuals and species and from season to season. For example, data from two loggerhead sea turtles tagged at the same location at Reunion Island (Fig. 1) illustrate completely different movement paths, with one animal moving North to Yemen and Oman, while the other animal moved south to visit the South African EEZ for some time – despite being part of the same population and tagged in the same year.[19]

[3] UNCLOS, art. 239.

[4] *Convention on the Conservation of Migratory Species of Wild Animals* opened for signature 23 June 1979, 1651 UNTS 356, (entered into force 1 November 1983), Appendix A1.

[5] CMS, Appendix II.

[6] Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations http://seamap.env.duke.edu/http://seamap.env.duke.edu/.

Table 1
The EEZs entered by 3 highly migratory marine species. Data obtained from the OBIS SEAMAP Archive.

	Leatherback turtle	Atlantic Bluefin Tuna	Humpback whale
African EEZs	Morocco, Western Sahara, Guinea-Bissau, Sierra Leone, Côte D'Ivoire, Ghana, Togo, Benin, Sao Tome and Principe, Cameroon, Gabon, Congo, Angola, Namibia, South Africa, Mozambique, Madagascar	Morocco, Algeria, Tunisia, Libya and Western Sahara	Morocco, Western Sahara, Nigeria, Cameroon, Cape Verde, Equatorial Guinea, Gabon, Congo, Angola, Namibia, South Africa, Madagascar, Mozambique and Comoros
European EEZs	Portugal (Azores and Madeira), France (French Guiana, Martinique), United Kingdom (Saint Helena, Bermuda), Spain, Belgium, Denmark (Faroe Islands) and Ireland	Spain, Portugal, Ireland, United Kingdom and Denmark (Faroe Islands)	Denmark, France (Mayotte, Martinique), Iceland, Norway, Portugal, Spain and United Kingdom
North American EEZs	United States, Mexico, Nicaragua, El Salvador, Guatemala, Cuba, Haiti, Bahamas, Jamaica, Dominican Republic, Panama, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, Antigua and Barbuda, Honduras, Barbados & Costa Rica,	United States, Canada, Cuba, Mexico, Haiti, Bahamas, Dominican Republic, British Virgin Islands (U.K.) and Anguilla (U.K.)	United States, Canada, Mexico, Panama, Barbados, Bahamas, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago and Barbados
Asian EEZs	Sri Lanka, Bangladesh, India, Indonesia, Singapore, Malaysia, Thailand, Vietnam, Qatar and Bahrain		China, Indonesia, Oman, Russia, Sri Lanka and Yemen
Oceania EEZs	Papua New Guinea, Vanuatu, Australia and the Solomon Islands		Australia, New Zealand, Papua New Guinea, Fiji, Solomon Islands, Niue and Cook Islands?
South American EEZs	Argentina, Brazil, Chile, Uruguay, Venezuela, Colombia, Guyana, Suriname, and Ecuador		(7)- Argentina, Brazil, Colombia, Ecuador, Peru, Uruguay and Venezuela
Total	67	17	57

The movements of humpback whales are similarly dynamic and unpredictable. For example, the migratory movements of one humpback whale tagged in the waters of the Antarctic Peninsula region entered the EEZs of 5 countries on its way to the Gulf of Panama (Fig. 2). However, a humpback whale captured photographically in essentially the same location was recaptured in the breeding grounds of American Samoa [20], a destination that is nearly 100 degrees of longitude away from the Gulf of Panama (Fig. 2). A straight–line path connecting these locations intersects the EEZs of three nations not visited by the tagged humpback (Fig. 2). Mark-recapture studies of humpbacks in the North Pacific also illustrate the unpredictable nature of these highly migratory species. Some animals photographically captured in Hawaii were recaptured in Canada, the US, and Russia. Furthermore, some of these individuals move amongst feeding and breeding locations over their reproductive lifetime [21].

Seabirds also exhibit highly variable and unpredictable movements, even when their feeding and breeding regions are well known. The movements of Arctic terns tagged in Greenland provide a compelling example of how unpredictable their interactions with national EEZs are [22]. Fig. 3 illustrates the paths of two Arctic terns tagged in 2007–2008. One animal visited 15 EEZs (one of which is disputed) during a year, spread between the northern and southern hemispheres. A second animal, tagged in the same location, visited a larger number of EEZs (16) during a year migration cycle including 9 EEZs not visited by the first tern.

Finally, large pelagic fishes are also studied through the use of bio-logging and they are similarly unpredictable in their movements post-tagging. For example, two Atlantic Bluefin tuna tagged in the waters of the US off North Carolina moved in essentially opposite directions over the course of the deployments (Data courtesy of Barbara Block, Stanford University). One animal spent time in the EEZs of the US and Eastern Canada, then moved south into the Gulf of Mexico after spending a brief amount of time in the EEZs of Cuba and Mexico (Fig. 4). The second animal, however, moved across the Atlantic and into the Mediterranean, and interacted with the EEZs of Algeria, Canada, Italy, Morocco, Portugal, Spain, and the United Kingdom on the way (Fig. 4). It should be noted here that in the case of most pelagic fish bio-logging, archival light-based geolocation tags are used, which only provide data on the movements of the animals after the tag is shed form the animal.

3. The law of the sea

The international law of the sea is codified in UNCLOS, which was adopted in 1982 after nine years of negotiation by a multilateral diplomatic conference. The treaty is the “constitution” for the world's oceans because it apportions rights and duties among flag states, coastal states, and port states concerning virtually every activity at sea.[7] Since UNCLOS entered into force in 1994 it has become “the legal framework within which all activities in the oceans and seas must be carried out.”[8] The convention reflects “sets of implicit or explicit principles, norms, rules, and decision-making procedures around which actors' expectations converge” concerning activity in the water column, on the seabed, on the surface of the ocean, and in the airspace above it.[9] Creation of the EEZ, which is neither territorial sea nor high seas, was one of the

[7] Tommy T.B. Koh, A Constitution for the Oceans, in *The Law of the Sea: United Nations Convention on the Law of the Sea with Index and Final Act of the Third United Nations Conference on the Law of the Sea* xxxiii, xxxiv (1982).

[8] UN Doc. A/68/PV.63, December 9, 2013.

[9] Krasner, S.D. “Structural Causes and Regime Consequences: Regimes as Intervening Variables.” (1982) International Organization 36: 185, 186.

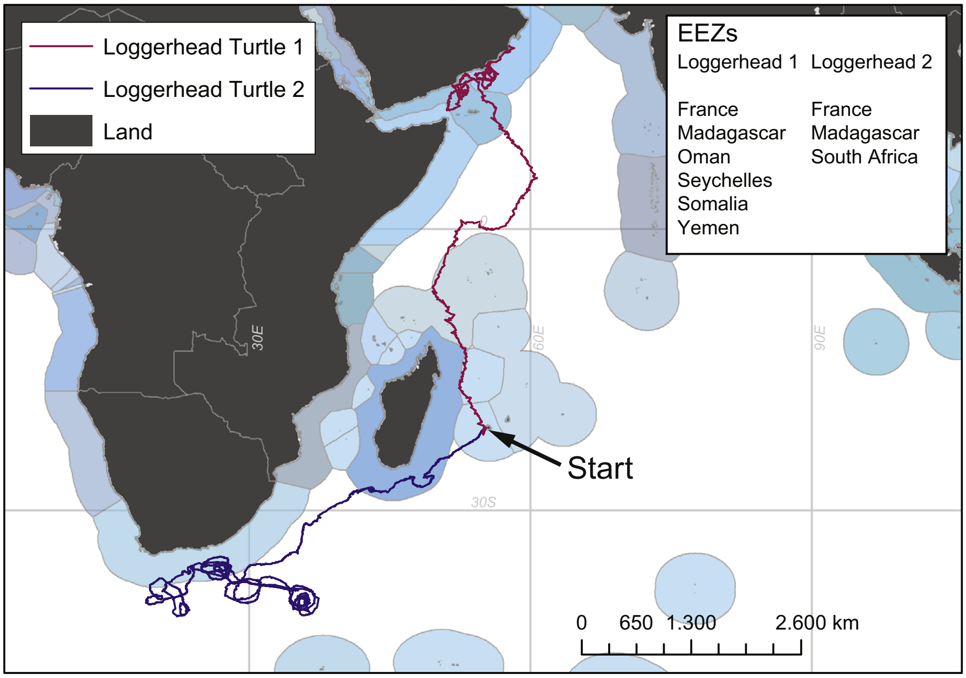

Fig. 1. The raw movement tracks and EEZs visited by two loggerhead turtles (*Caretta caretta*) tagged with satellite transmitters on Reunion Island in 2011–12 [19]. Data courtesy of Kelonia/IFREMER.

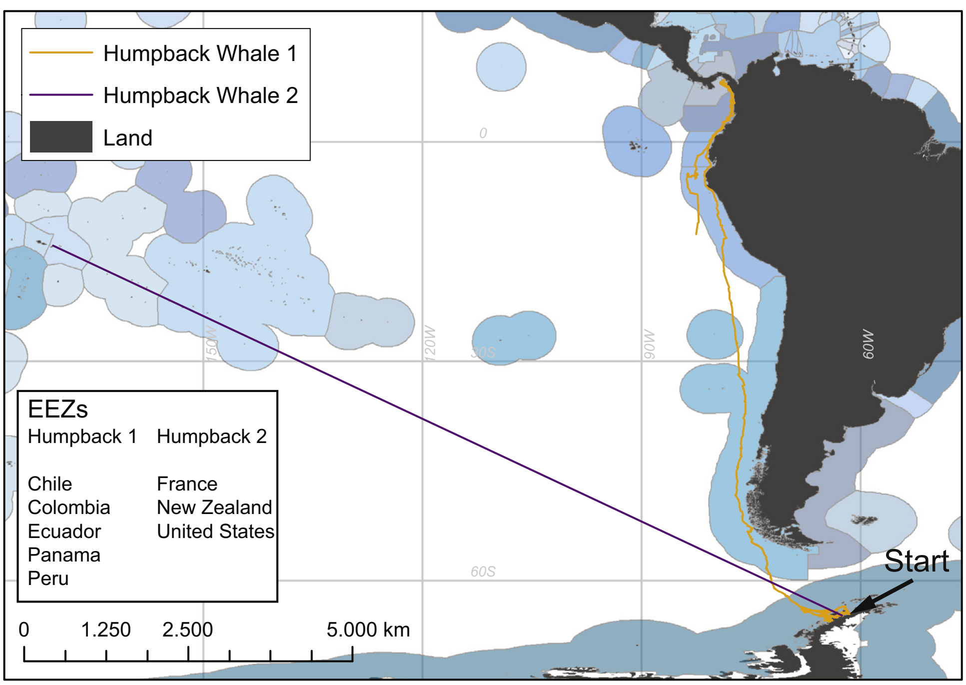

Fig. 2. The raw movement tracks and EEZs visited by of two humpback whales (*Megaptera novaeangliae*). Humpback 1 was satellite tagged in the Western Antarctic Peninsula region during 2012. Humpback 2 was captured photographically in American Samoa in 2005 and recaptured in the WAP in 2009.

greatest innovations in UNCLOS, and it created the right and expectation among coastal states that they have exclusive sovereign rights in living resources to a distance of 200 nautical miles (nm) from shore, as well as jurisdiction over MSR in the zone. UNCLOS also recognizes a 12 nm territorial sea, over which the coastal state may exercise sovereignty. Consequently, bio-logging potentially implicates coastal state sovereignty in the territorial sea, and two coastal states interests in the EEZ: exclusive sovereign rights in the living resources and jurisdiction over MSR. Marine migratory species, however, are oblivious to the coastal zones established by UNCLOS, and the legal regimes that apply within them.

3.1. Sovereignty in the territorial sea

Coastal states enjoy sovereignty over the water column, airspace, and seabed of the territorial sea. Other states may access the territorial sea for the purpose of innocent passage – the “continuous and expeditious” transit of the zone in a manner that does not affect the “peace, good order o security of the

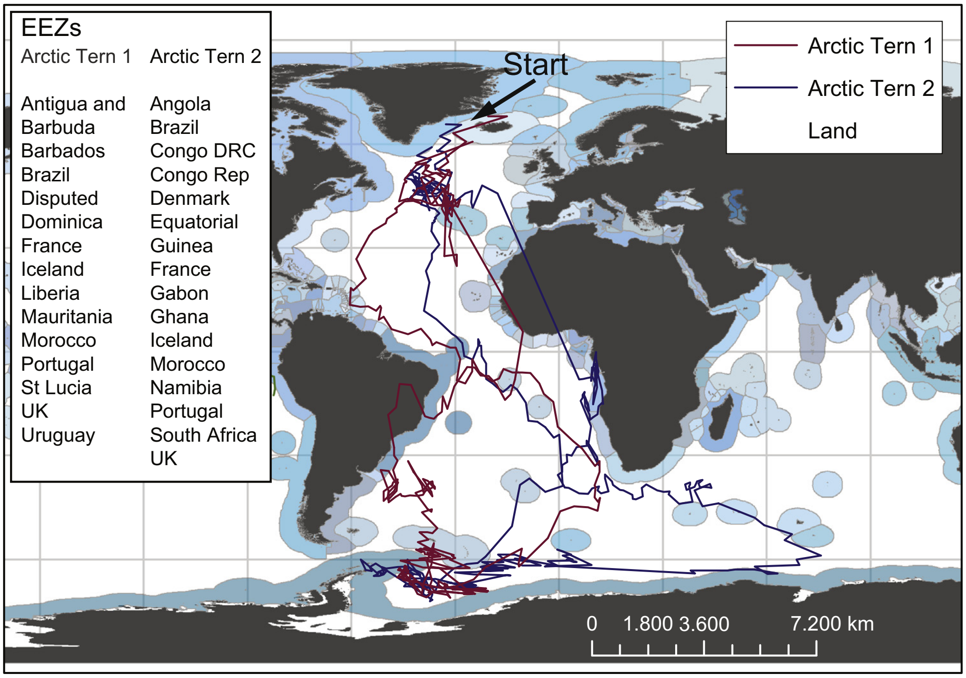

Fig. 3. The raw movement tracks and EEZs visited by two Arctic terns (*Sterna paradisaea*) tagged with satellite transmitters in Greenland/Iceland in 2007 [22]. Data courtesy of the Greenland Institute of Natural Resources.

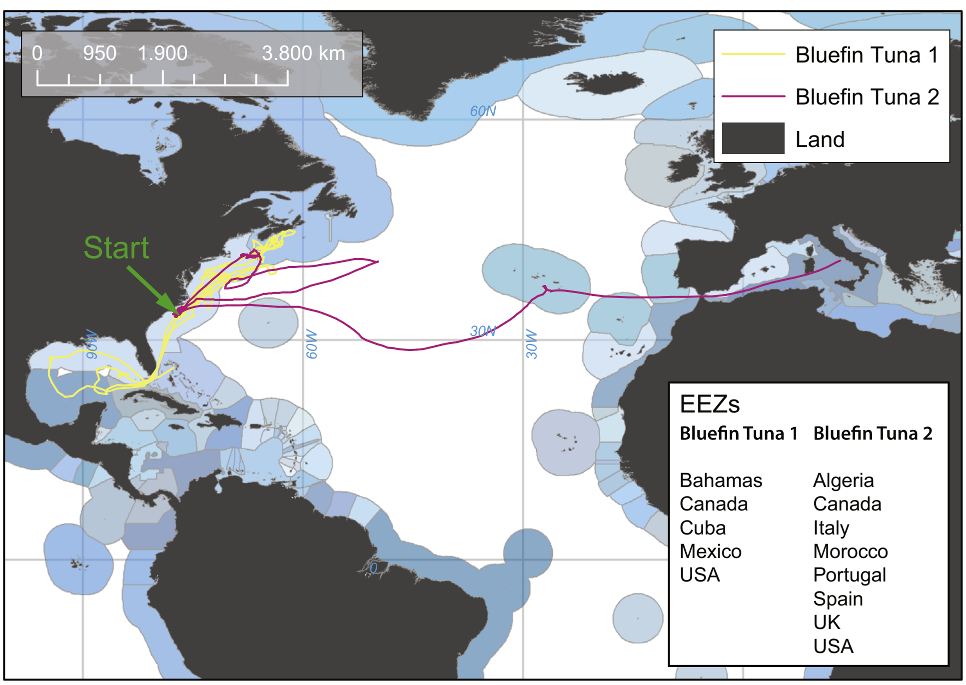

Fig. 4. The raw movement tracks and EEZs visited by two Atlantic bluefin tuna (*Thunnus thynnus*) tagged with archival light-based geo-location tags of North Carolina, in 2009. Data courtesy of Barbara Block, Stanford University.

coastal state."[10] Research and survey activities are inconsistent with innocent passage.[11] The "express consent" of the coastal state is required for the conduct of MSR in the territorial sea.[12] There is no exception to the requirement to receive coastal state consent for the conduct of MSR by ships engaged in innocent passage. Furthermore, in the territorial sea all states enjoy a right of entry, and the right to render assistance to mariners in distress, under conditions of force majeure.[13]

These rules appear on their face to suggest marine scientists should seek and obtain coastal state consent for MSR in the territorial sea. This proscription, however, is limited to the physical

[10] UNCLOS, art. 17–19.

[11] UNCLOS, art. 19(2)(j).

[12] UNCLOS, art. 245.

[13] UNCLOS, art. 18(2). See also U.S. Coast Guard COMMANDANT INSTRUCTION 16451.9, U.S. Coast Guard Places of Refuge Policy, July 17, 2007, para. 5(i).

presence of a vessel or scientist within the territorial sea. Merely studying the territorial sea remotely, either through satellite or from aircraft in flight beyond the outer limits of the territorial sea – or marine bio-logging – does not undermine the sovereignty of the coastal state.

3.2. Resource rights in the EEZ

The EEZ constitutes about 40 per cent of the world's oceans – the coastal zone that includes estuarine, green and brown water habitat and the most productive marine ecosystems. These areas are under the resource jurisdiction of coastal states.[14] Coastal states have sovereign rights for the purpose of exploring or exploiting, conserving and managing living resources in the EEZ.[15] Indeed, the primary motivation for creation of the EEZ was to afford coastal states the ability to manage offshore living and non-living resources, and to ensure that the benefits of their use inures to the coastal state. It might be suggested that bio-logging constitutes "exploring" living resources in the EEZ because information obtained may indicate areas of species migration or reproduction, or suggest areas especially rich for exploitation. In this regard, data from bio-logging is likely to be important for conservation and management of marine species, further implicating the sovereign rights of the coastal state. On the other hand, the data collected is serendipitous – scientists have little or no ability to predict what data will be collected. Furthermore, movement data may help to better understand or inform conservation of an entire species, but it does not infringe on the coastal state's sovereign rights because the marine species and not the scientists that use bio-logging are controlling their movement.

3.3. Marine scientific research in the EEZ

Similarly, the use of bio-logging does not undermine the coastal state's authority over the conduct of traditional MSR in the EEZ.

Other states enjoy a range of rights and freedoms in a coastal state's EEZ, including the freedom of navigation, overflight, freedom to lay submarine cables and pipelines, and other internationally lawful uses of the sea, as well as the conditional freedom to construct artificial islands and other installations, freedom to fish, and freedom of MSR. The latter right, however, is subject to coastal State consent.[16]

Section 3 of Part XIII of UNCLOS established a regulatory framework for MSR in the EEZ that skews authority toward coastal states. The expectation to obtain coastal state consent for MSR in the EEZ and on the continental shelf is set by Article 246 of the Convention, and it affects the behavior of states and scientists. In "normal circumstances" coastal states shall grant their consent for MSR.[17] Coastal states may withhold consent for research in the EEZ and on the continental shelf that has "direct significance" for natural resources, and those involving drilling on the continental shelf, the use of explosives, or the construction of some artificial islands and structures or that introduce toxic substances into the sea.[18] Furthermore, the coastal State has the right to require the suspension of the research project in progress within its EEZ if it does not comply with these rules.[19] MSR conducted inside the EEZ of a coastal state sometimes has pitted scientists seeking to conduct research against coastal states that withhold consent, or make onerous demands to obtain it.[20]

This framework reflects the type of in situ research model that originated from the nineteenth century voyages of the HMS *Challenger* (1872–76). Oceanographic vessels and traditional research conducted over the side of the ship are a physically intrusive presence in the territorial waters and EEZ. In contrast, remote sensing techniques and virtual presence eliminates the intrusive nature of traditional MSR. The new MSR, therefore, neither implicates the coastal states' authority over scientific research physically conducted in its EEZ, and therefore does not require its consent.

3.3.1. Contrast with floaters and gliders

In order to maximize their jurisdiction offshore, coastal states are inclined to a broad and inclusive definition of marine scientific research. States have debated, for example, whether collection of routine meteorological and oceanographic observations by voluntary observing ships, floats, and gliders, and activities such as marine surveys and bio-prospecting, constitute MSR [23] In a response to an inquiry by the World Meteorological Organization on whether routine marine observations and data collected for sea state estimation, weather forecasts, and climate modeling constitute "marine scientific research," the chairman of the Third United Nations Conference on the Law of the Sea responded that they lie outside the regime of MSR.[21] The United States has relied in part on this opinion to express the same view.[22] The use of marine migratory species as oceanographic platforms adds to this milieu of discord and debate over the role of the coastal state in the MSR regime. Marine animals can be tagged anywhere in the world, and later through natural movement and migration, they may end up in areas under coastal state jurisdiction.

The Intergovernmental Oceanographic Commission has issued guidance on the use of floating buoys or gliders inside a coastal state's EEZ as part of a program pursuant to an international marine science effort. The guidance permits states to require notification in certain circumstances. A state must be notified if the deployed device "might" enter the EEZ of a participating state that has so requested notification "reasonably in advance of the expected entry of the float in the EEZ."[23] This guidance, however, does not control the use of marine animals as platforms to collect marine data; bio-logging is not analogous. The difference between the two is that marine species follow unpredictable courses driven by decisions made by the animals themselves, whereas drifting buoys and floating instruments are driven by predictable wind and currents, and their intended trajectories are often modeled ahead of deployments as part of the studies they support. Furthermore, deployed floats, gliders and drifters are also recoverable, whereas tags deployed on animals are not.

[14] UNCLOS, art. 56.
[15] UNCLOS, art. 56(1)(a).
[16] UNCLOS, arts. 58 and 87.
[17] UNCLOS, arts. 246(3).
[18] UNCLOS, arts. 246(5).
[19] UNCLOS, arts. 253.

[20] The difficulty in obtaining clearance for MSR in foreign EEZs was evident even before UNCLOS entered into force. See, for example, Ross and Fenwick. U.S. Marine Scientific Research and Access to Foreign Waters, Oceanography 37–39 (November 1988) and Fenwick, International profiles on marine scientific research: national maritime claims, MSR jurisdiction, and U.S. research clearance histories for the world's coastal states (International Marine Science Cooperation Program, WHOI Sea Grant Program, Woods Hole Oceanographic Institution, Woods Hole, MA 1992).
[21] Third United Nations Conference on the Law of the Sea, 14 Official Records 102–3.
[22] IOC Doc. IOC/ABE-LOS VII/8, memorandum of the IOC/ABE-LOS Sub-Group on the IOC legal framework for the collection of Oceanographic Data within the context of UNCLOS, 19.
[23] IOC Res. IOC/EC-XLI.4, IOC Guidelines for the Implementation of Resolution XX-6 of the IOC Assembly Regarding the Deployment of Profiling Floats in the High Seas within the Framework of the Argo Programme, adopted by the IOC Executive Council at its 41st session, Paris 24 June–1 July 2008, Annex, para. 3.

Bio-logging is further differentiated from other marine data collection activities because the course, track, and behavior of specific tagged animals are largely unpredictable and, essentially unknowable, when instruments are deployed. This is especially true for archival tags deployed on marine animals that do not provide information about the movements of animals until they are recovered or are jettisoned from the animal. Consequently, while bio-logging is indeed a new form of MSR and therefore falls within Part XIII of UNCLOS, the activity is “conducted” at the point that the tag is placed on a marine animal – not at every location that data is collected as the animal migrates through the oceans.

4. Conclusion

It sum, bio-logging initiated beyond the limits of the territorial sovereignty or resource jurisdiction of coastal states is consistent with international law, and in particular, UNCLOS. Coastal states may not purport to require their permission and marine scientists are not compelled to seek it, even if tagged marine species later migrate into the territorial sea or EEZ. As in many areas of society, technology has leapfrogged existing legal regimes. Bio-logging illustrates how the authority of coastal states to monopolize information about, and direct and control the study of, marine migratory species has diminished. The use of bio-logging does not mean, however, that coastal state sovereignty over the territorial sea, or exclusive resource rights in the EEZ have contracted. Instead, new methods of MSR have by-passed the existing regulatory regime, much as satellite remote sensing did decades earlier. Likewise, just as remote sensing advanced understanding of the Earth, bio-logging is expanding the horizon of marine science, and improving the ability to develop and support programs for marine conservation.

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Appendix A1. Highly migratory species identified in UNCLOS

1. Albacore tuna: *Thunnus alalunga*.
2. Bluefin tuna: *Thunnus thynnus*.
3. Bigeye tuna: *Thunnus obesus*.
4. Skipjack tuna: *Katsuwonus pelamis*.
5. Yellowfin tuna: *Thunnus albacares*.
6. Blackfin tuna: *Thunnus atlanticus*.
7. Little tuna: *Euthynnus alletteratus; Euthynnus affinis*.
8. Southern bluefin tuna: *Thunnus maccoyii.*
9. Frigate mackerel: *Auxis thazard; Auxis rochei*.
10. Pomfrets: Family Bramidae.
11. Marlins: *Tetrapturus angustirostris; Tetrapturus belone; Tetrapturus pfluegeri; Tetrapturus albidus; Tetrapturus audax; Tetrapturus georgei; Makaira mazara; Makaira indica; Makaira nigricans.*
12. Sail-fishes: *Istiophorus platypterus; Istiophorus albicans.*
13. Swordfish: *Xiphias gladius. Sauries: Scomberesox saurus; Cololabis saira; Cololabis adocetus; Scomberesox saurus scombroides*.
14. Dolphin: *Coryphaena hippurus; Coryphaena equiselis.*
15. Oceanic sharks: *Hexanchus griseus; Cetorhinus maximus*; Family Alopiidae; *Rhincodon typus*; Family Carcharhinidae; Family Sphyrnidae; Family Isurida.
16. Cetaceans: Family Physeteridae; Family Balaenopteridae; Family Balaenidae; Family Eschrichtiidae; Family Monodontidae; Family Ziphiidae; Family Delphinidae

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