The suitability of the North Sea as a habitat for Atlantic Bluefin Tuna

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Contents

Summary

A scoping study has been conducted to determine the suitability of the North Sea as an environment for Atlantic Bluefin tuna (ABFT). The study involved a thorough literature review and an examination of data on the abundance of ABFT prey species in the region and an analysis of the potential threats to ABFT in the North Sea. A list of the relevant literature concerning ABFT is included.

Indications are that the North Sea is a suitable summer feeding environment for Atlantic Bluefin tuna given the role that this area has previously played in the lifecycle of this stock. Prey availability should be sufficient and there are limited threats to ABFT in comparison to other parts of the stock's distribution. The feeding distribution of ABFT has increased in recent years as the stock has grown, with sightings of ABFT off the Outer Hebrides and Norwegian waters, near to the northern North Sea. Translocation experiments may prove unnecessary should the stock continue to grow and expand its distribution, potentially into the North Sea.

1. Assignment

ABFT was once common in the North Sea in the mid-summer to Autumn (June to October), but since the 1950s this is no longer the case. This report examines whether or not the North Sea remains a suitable habitat for ABFT and what enabling conditions, in relation to factors determining the North Sea's suitability as a habitat, are required for a successful return and possible reintroduction of ABFT.

1.1 Aims

This project aims to provide background information about the suitability of the North Sea for ABFT based on existing literature and data, in order to answer a number of key questions:

1. What was the role of the North Sea in relation to the ABFT life history in the past?

2. Given this, how suitable is the North Sea today to fulfil that role?
   - Assess the suitability of the North Sea as a summer/autumn habitat for ABFT in terms of environmental/oceanographic and ecological conditions (predators/prey) and seasonality due to migration patterns
   - What threats to ABFT exist in the North Sea?

3. What will the North Sea look like for ABFT in the future?
   - Assess potential future trends and scenarios for the North sea in relation to environmental/oceanographic and ecological conditions (predators/prey)

In addition, the current regulations regarding ABFT in the North Sea will be summarized and gaps in our data and understanding regarding this species in the North Sea are identified.

2. Background information

Bluefin tuna (*Thunnus* sp.) are iconic top predators found throughout the subtropical and temperate waters of the Atlantic and Pacific oceans and adjacent seas, such as the Mediterranean (Collette and Nauen 1983, Figure 2.1). Given the broad global distribution, two subspecies were recognized by Gibbs and Collette (1967): *T. thynnus thynnus* (Linnaeus) in the North Atlantic and *T. thynnus orientalis* (Temminck & Schlegel) in the North Pacific. Collette (1999) now advocates separation of these bluefins into Atlantic, *T. thynnus*, and Pacific, *T. orientalis*, species. The current reports deals with Atlantic Bluefin tuna (*T. thynnus*) only.

In the North Atlantic spawning occurs in two locations: the Mediterranean and the Gulf of Mexico. For management purposes these two spawning components are treated as separate stocks, conventionally separated by the 45°W meridian. While ABFT has been known to cross the Atlantic (Rooker et al. 2008, 2014), the contribution of eastern ABFT to spawning in the west, and vice versa, is considered to be low. Rooker et al. (2008) found that adults showed high rates of natal homing (both eastern and western) even though trans-Atlantic movement (particularly east to west) was significant. Rooker et al. (2014) confirmed that the degree of mixing declined with proximity to the eastern spawning area (Mediterranean Sea), concluding that few western migrants enter the Mediterranean Sea. Further investigations are ongoing to develop a greater understanding of the complex population structure of ABFT.

They undergo extensive annual migration between spawning areas and summer feeding grounds, displaying homing behaviour and spawning site fidelity. Feeding migrations within the Mediterranean and the North Atlantic are less well understood than spawning behaviour, but results from electronic tagging indicated that ABFT movement patterns vary considerably between individuals, years and areas.

While Bluefin tuna are epipelagic and oceanic, at some times of the year they can be found inshore. They are also known to dive to depths of greater than 1000m. They are a long-lived and highly valuable species and due to their position in the food web they play an important role in the marine ecosystem that they inhabit. Historic overfishing has led to a reduction in the abundance of this species in recent times. Currently Atlantic Bluefin tuna is listed as 'endangered' by the International Union for Conservation of Nature and Natural Resources (IUCN) and was highlighted by the World Wildlife Fund (WWF) as a species threatened by wildlife trade for World Wildlife Day in 2014.

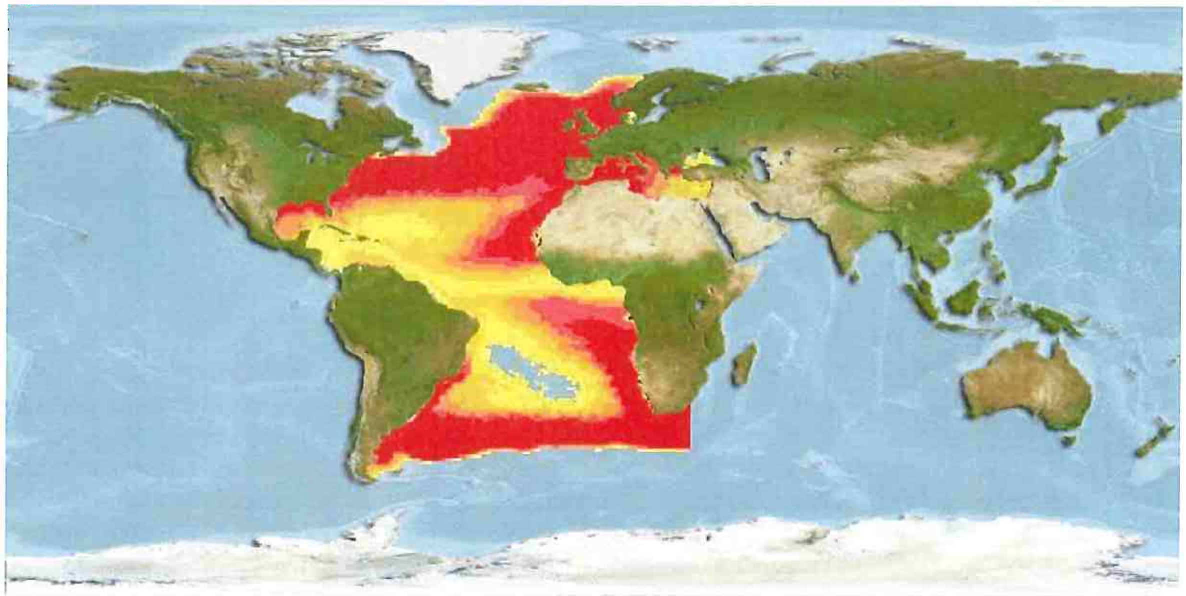


Figure 2.1. The distribution of Atlantic Bluefin tuna (source: Reviewed Native Distribution Map for *Thunnus thynnus* (Atlantic bluefin tuna). www.aquamaps.org, version of Aug. 2013. Web. Accessed 8 Oct. 2014.).

In the eastern stock, spawning occurs in the Mediterranean from June through August. Juvenile ABFT grow rapidly, growing to approximately 60 cm in the first year, attaining a weight of about 4 kg. Eastern ABFT mature at an earlier age and much smaller weight than western ABFT (25 kg at age 4 and 145 kg at age 9, respectively). At 10 years old, a bluefin tuna is about 200 cm and 170 kg and reaches about 270 cm and 400 kg at 20 years (ICCAT, 2012). Bluefin tuna is a long-lived species, with a lifespan of about 40 years, as indicated by studies from radiocarbon deposition (Neilson and Campana, 2007).

Bluefin tuna exhibit strong schooling behaviour while they are young. Rather than forming single species schools, juvenile tuna school by size, sometimes together with other similar fish such as other tuna species e.g. albacore, yellowfin, bigeye, skipjack, frigate tuna. This schooling behaviour allows for more efficient hunting of schooling pelagic prey. Packs form high-speed parabolas, concentrating the prey into a 'bait ball' (Figure 2.2), allowing for more efficient capture. Bluefin are ideally suited for high-speed chases, but they are highly opportunistic feeders, allowing them to take advantage of whatever food sources may be present.

Figure 2.2. Tuna attack a bait ball of smaller fish. (Photograph © Galate Films).

2. 1 Stock status

Atlantic Bluefin tuna is current listed as 'Endangered' on the IUCN Red List of Threatened Species (Collette et al, 2011). This Atlantic species has experienced declines in range and reported catch per unit effort (CPUE) since the 1960s. Although a number of uncertainties exist in the reported data, especially from the Mediterranean region, the best estimates from the most recent 2010 stock assessment indicate that there has been a global decline of between 29% and 51% based on summed spawning stock biomass (SSB) from both the Western and Eastern stocks over the past 21–39 years (three generations, based on a generation length of between seven and 13 years). Pre-exploitation longevity is not known for the Eastern Atlantic, but it is assumed that at one point this species had a similar longer generation length across its global range. Therefore, this species is estimated to have declined at least 51% over the past three generation lengths (39 years) and is listed as Endangered under Criterion A2. In the Eastern Atlantic stock, current fishing mortality is far above maximum sustainable yield (MSY) and estimated SSB is far below MSY. The Western Atlantic stock has experienced severe declines in the past, is also below MSY, and has not recovered under current fishing regimes. Management of the eastern Atlantic stock is essential to the future of this species, as it represents the majority of this species global population.

For management purposes, the ABFT stocks are assessed by the International Council for the Conservation of Atlantic Tunas (ICCAT, 2012). Assessing the status of widely distributed and highly migratory fish such as AFBT is challenging. The most problematic element of the ABFT assessment is the representativeness of catch statistics. In spite of recent improvements in the data quantity and quality for the past few years, in the past poor temporal and spatial coverage for detailed size and catch-effort statistics and a potentially significant IUU (illegal, unreported and unregulated) component of the catches has compromised the quality of the data used in the assessment. In addition, the prevalence of tuna farming in recent years has lead to difficulties in determining the age composition of fish destined for fattening and farming operations, with this lack of demographic information further complicating the Atlantic bluefin tuna stock assessment (Milatou and Megalofonou, 2014). Modifications to assessment methodologies are planned to better accommodate the substantial uncertainties in the historical total catch, catch-at-age and effort data from the main fleets harvesting bluefin tuna. However, these are only likely to be complete in 2015. Nevertheless, the most recent assessment of the stocks (ICCAT, 2012) examines potential scenarios of past stock history, all of which show similar trends (though absolute estimates may be imprecise).

Eastern Stock

The assessment results indicate that the spawning stock biomass (SSB) reached a historic (estimated) high of approximately 300 kt during the 1960s. There was subsequently a substantial decline in biomass of approximately 50% from the 1970s until the mid-2000s. All assessment scenarios considered show clear signs of increase in the most recent years (Figure 2.3). However, the magnitude and the speed of the SSB increase remains highly uncertain, and is likely sensitive to the assumptions made about IUU catches in the past. The main driver of the increase in SSB appears to be a sharp decrease in fishing mortality (F) for the younger ages (ages 2-5), which after a prolonged period of increase has fallen to a historical low level. Fishing mortality on the older fish (ages 10+) was high from the mid-1990s to the mid-2000s, following a shift towards targeting larger individuals destined for fattening and/or farming, but fishing mortality on these ages has also subsequently decreased in recent years. Recent fishing mortality is below the reference target value of $F_{0.1}$ (a reference point used as a proxy for F_{MSY}, $F_{0.1}$= 0.7 and 0.36 for the reported and inflated catch scenarios, respectively).

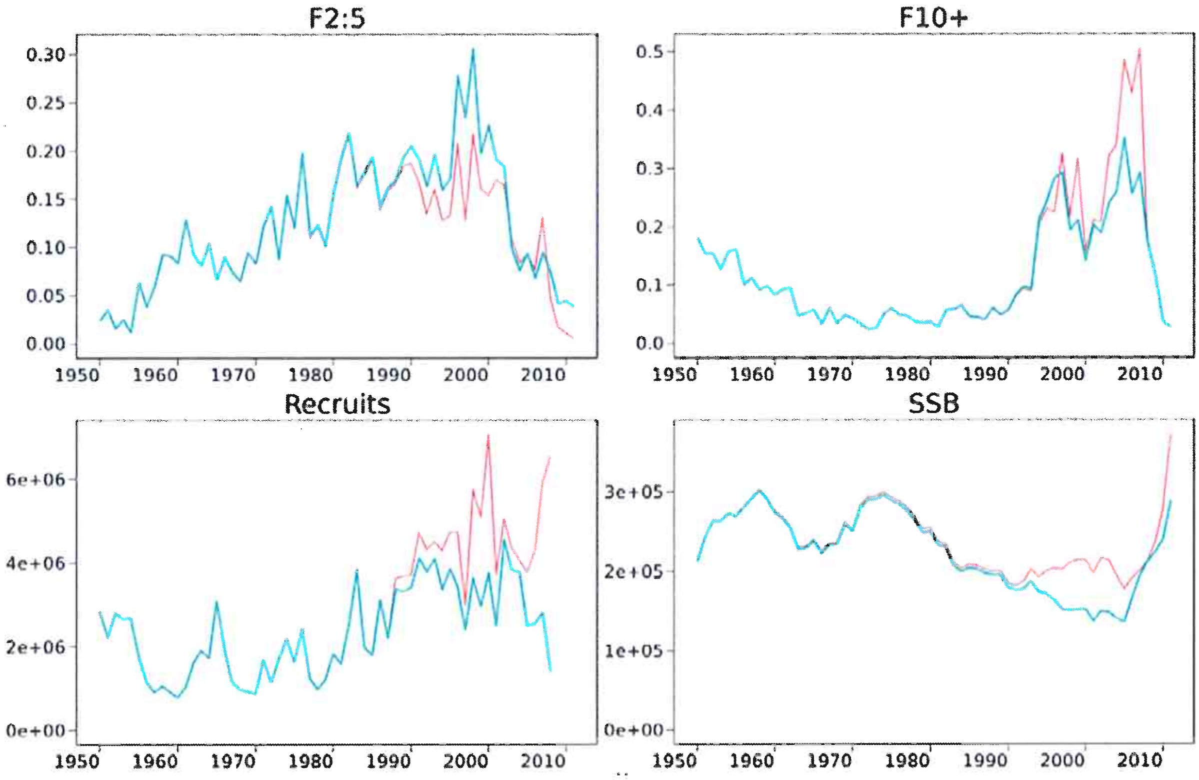


Figure 2.3. Result of the 2012 ICCAT assessment of the Eastern Atlantic Bluefin Tuna stock (from ICCAT, 2012). Fishing mortality on the younger ages (top left) and the older ages (top right), recruitment (bottom left) and spawner stock biomass (SSB, bottom right). The blue line indicates the base case assessment model using all valid and available data, the red line indicates a scenario including assumed unreported catches in the 1990s and early 2000s.

Western stock

While fish from the western stock are known to cross the Atlantic, it is more likely that Bluefin tuna in the North Sea would have come from the nearer eastern stock. While there has been some recovery in the eastern stock, the 2012 assessment estimated trends (Figure 2.4) indicate that the western stock, which declined in the 1970s, has remained at low levels of abundance since (fluctuating between 25% and 36% of the 1970 level). The stock has experienced different levels of fishing mortality (F) over time, depending on the size of fish targeted by various fleets, and recently fishing mortality on spawners (ages 9 and older) has reduced.

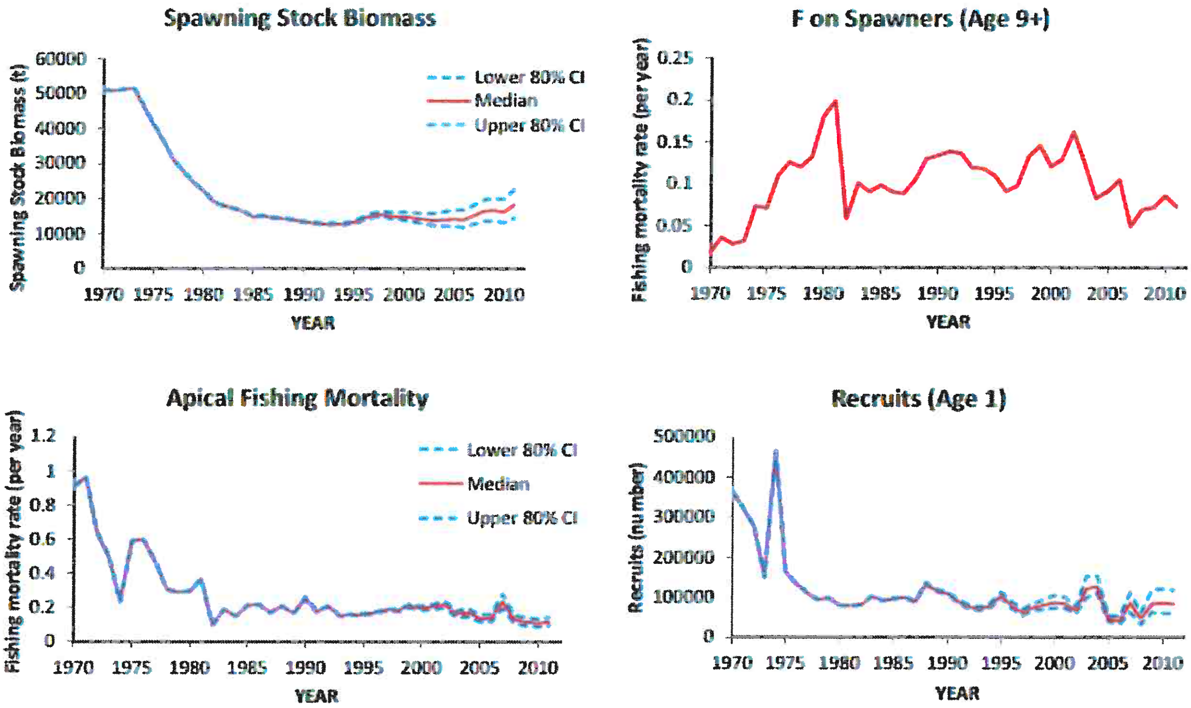


Figure 2.4. Result of the 2012 ICCAT assessment of the Western Atlantic Bluefin Tuna stock (from ICCAT, 2012). Median estimates of spawning biomass (age 9+), fishing mortality on spawners, apical fishing mortality (F on the most vulnerable age class) and recruitment for the base VPA model. The 80% confidence intervals are indicated with dotted lines. The recruitment estimates for the last three are replaced by the median levels corresponding to the low recruitment scenario.

3. The role of the North Sea

3. 1 Past

In the 1800s and early 1900s, ABFT was commonly found in the northern and central North Sea during the summer and early autumn (Le Gall 1927, Russell 1933a,b). Le Gall (1927) noted that tuna (Thon Rouge / Bluefin tuna) was frequently observed in the North Sea in the 1800s. All observations were made between the months of July and November (Figure 3.1). It was suggested by Delsman (1933) that the very warm and dry summer of 1911 may had contributed to maxima of plankton species that were several times higher than in normal years. In this year, tuna was observed by herring fishermen, which may also have been a result of the calm conditions that are favourable for noticing tuna at the water surface.

Tuna was abundant enough to form the basis of a sizable fishery in the region (Figure 3.2, ICCAT 2012). The main North Sea fishery began after WWI. For reasons not fully understood, but potentially due to overexploitation of the stock both in the North Sea and other areas of its distribution, the occurrence of ABFT in the North Sea began to decline in the 1950s. By the 1960s the occurrence of ABFT in the North Sea had declined substantially. It was suggested that the sudden collapse of these fisheries in 1963 resulted from a lack of migrating mature tunas in the northern area (Tiews, 1978 in Fromentin and Powers, 2005).

I. Mer du Nord.

Auteurs	Lieux de capture	Année	Mois	Observations
DONOVAN, puis YARREL, DAY.	Margate, entrée de la Tamise	1801	?	Trois exemplaires vendus à Billingsgate.
GORDON, puis YARREL, DAY	Moray Firth	1850	Juil.	abondants, taille jusqu'à 3 mètres.
do. do. do.	Au large de Craithie	1850	?	1 m 77 de circonférence, 2 m 74 de long. Conservé à Marischal College. Aberdeen.
DAY, aprèsGORDON.	Inverness	1850	..	1 m 52 de long.
YARRELL.	Au large de Chesil Beach.	1850	Juil.	2 m 43 de long.
HOGG, puis DAY	Tees Bay, près Hartlepool.	1853	Sept.	Poids 217 Kgs.
DAY.	Firth of Forth.	1868	Nov.	Un. Poids 250 Kgs.
DAY.	Yarmouth.	1870	6 Oct.	Un. 2 m de long.
DAY.	Bac on, près Haisborough	1876	Nov.	Un. 2 m 83 de long.
GATCOMBE, puis DAY.	Au large de la côte du Norfolk et du Suffolk.	1877	..	Rencontrés à différents reprises avant 1877. Un exemplaire à la côte, un autre à Southwold, conservé au Norwich Museum.
DAY.	À la côte du Comté de Kent.	1880	..	Un exemplaire.
MAC INTOSH.	Le "Traith", près Pittenweem côte N. du Firth of Forth.	1885	17 Oct.	Pris au chalut. 2 m 74 de long. Poids 340 kgs.

Figure 3.1. A table and figure taken from Le Gall (1927) noting the location and timing of tuna ('tunny'/Thon Rouge) observations in the North Sea in the 1800s.

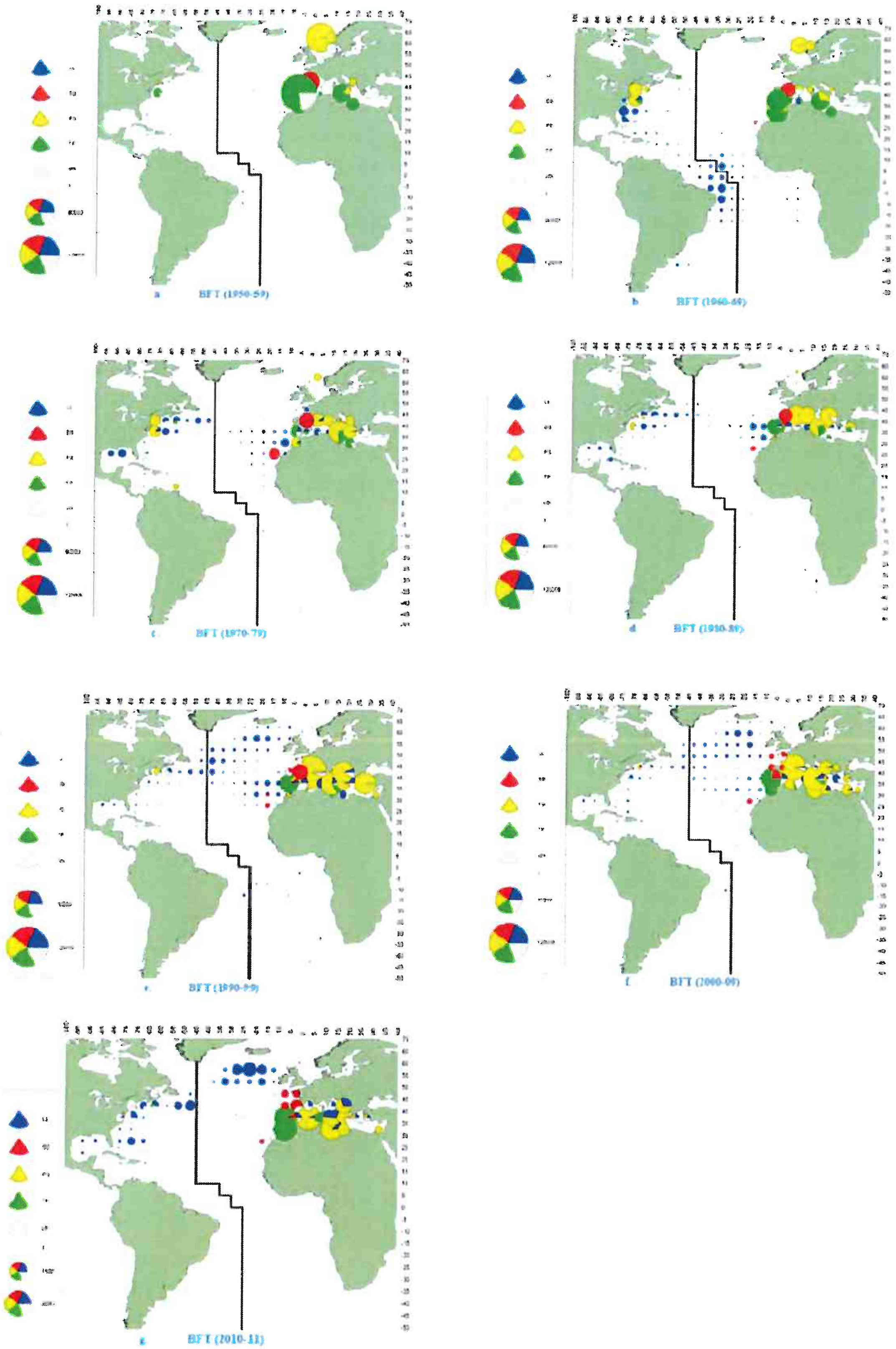


Figure 3.2. Decadal geographic distribution of Atlantic Bluefin tuna catches per 5X5 degrees and by main gear types (blue = longline, red = bait boats, yellow = purse seine, green = traps, and grey = other).

Information on tuna in the North Sea before the 1950s mainly rely on sightings and catches from fisheries. The North Sea was considered as one of the foraging areas that bluefins migrated to after spawning in some confined areas in the Mediterranean Sea, as reviewed by Trenkel et al (2014). Other foraging areas near the North Sea included the Bay of Biscay, the Norwegian Sea, and areas west of Ireland and south of Iceland. In the North Sea, it has been reported that older/larger individuals used to enter first, and juveniles appeared later in summer (MacKenzie and Myers 2007). This might be caused by the distance, since it appears that the North Sea was entered from the Northern Atlantic rather than through the channel. Before the collapse of fisheries in 1963, the size composition of ABFT caught by the Norwegian fleet included fish from 140 to 250 cm (50-200 kg) (Tiews, 1978 in Fromentin and Powers, 2005).

Migration into the North Sea occurred from the Northern Atlantic, and not through the English Channel (Fromentin and Powers, 2005; Figure 3.3.). In the North Sea and the Norwegian Sea ABFT fed on herring, mackerel, sprat, garfish and gadoids (Tiew, 1978). This enabled them to increase their weights and condition factors before starting the return the return migration to southern waters in autumn (Tiews, 1978). Tiews (1978) assumed a stay of 100 days in the North Sea in his calculations to assess daily food intake.

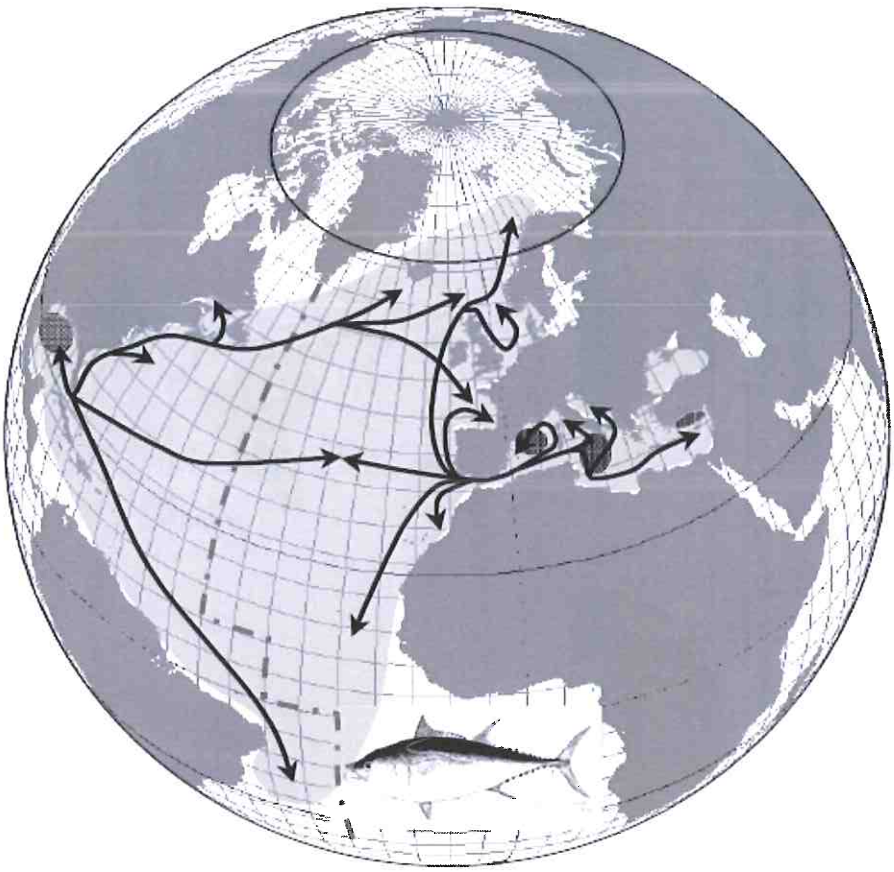


Figure 3.3. Spatial distribution of Atlantic bluefin tuna (gray shading) and main migration routes (black arrows) are deduced from current and historical fisheries data as well as traditional and electronic tagging information. The vertical dashed dotted line depicts the stock delimitation between the two current ICCAT management units. (reproduced from Fromentin and Powers 2005).

The schools of migrating spawners included a broad range of individual sizes (and ages) and their quantity seemed to fluctuate in relation to environmental conditions (Ravier and Fromentin, 2004). Eastern and western populations migrate and mix in the Central Atlantic Ocean, but the degree of mixing declines with proximity to the eastern spawning areas, located in the Mediterranean Sea. This suggests that the eastern stock was the likely stock of origin for ABFT found in the North Sea. It also appears that eastern ABFT exhibit natal homing (Rooker at al., 2014), i.e. adults return to their birthplace to reproduce.

In the 1960s the stock of ABFT strongly declined (ICCAT, 2012). Several hypotheses have been tested, including the effect of low temperatures, decreases in prey abundance, changes in migration patterns, over fishing and the impact of environmental factors on recruitment.

- Except for the cold winter of 1963, sea surface temperatures during the 60s in the North Sea were similar to earlier decades (Becker and Kohnke, 1978). So, low temperatures are not likely for the decrease in bluefin tunas in the North Sea.
- Herring populations, a major food source for ABFT in the North Sea, showed a marked decrease during the 60s and 70s (Dickey-Collas et al. 2010; ICES, 2012). This may have altered their migration pattern towards other areas.
- It appears that young ABFT did not migrate into the northern Atlantic waters, since the size of tunas caught increased (Pusineri et al., 2002). So, either recruitment was low, and/or young tuna changed their migration pattern. Ravier and Fromentin (2004) suggest that ABFT are likely to perform repeat homing behaviour, i.e. a process related to spatial learning of the younger ones from the older individuals. Once older fish had stopped returning to the North Sea, there would have been no spatial learning amongst juvenile tuna that would reinforce migrations back to the North Sea.

In recent years, despite continued exploitation and potentially large unreported catches, there are indications that the stock biomass is increasing. Over the last decades, a progressively earlier arrival in the Bay of Biscay has been observed (Dufour et al., 2010), potentially an impact of climate warming. Along with this an expansion of the distribution of the stock further north in the Atlantic and into the western channel area has been observed (see various anecdotal reports in reading list, occurrence of a stranding in Zeeland, anecdotal word of bycatches off Norway etc.).

3. 2 Present

The suitability of the North Sea as a habitat for Bluefin tuna can be examined based on the role the North Sea used to play in the life history of Bluefin tuna, i.e. as a feeding ground. The likely availability of prey and potential threats to ABFT whilst in the North Sea are described in this section, with abiotic conditions described in Section 3.3.

3.2.1. *Prey availability*

Juvenile and adult bluefin tuna are opportunistic predators. They have a broad adaptable diet, that varies from region to region depending on availability of prey. A sample of 568 Atlantic Bluefin tuna from different study areas yielded at least 21 species of teleost fish, two of elasmobranch fish and at least nine of invertebrates in the stomach contents (Chase, 2002). These included even jellyfish and salps but also other demersal species, crustaceans and cephalopods. In the North Sea and the Norwegian Sea ABFT fed on herring, mackerel, sprat, garfish and gadoids (Tiew, 1978).

While they have an adaptable diet, the older fish, which are expected to be found in the North Sea, primarily feed on fish such as herring, anchovy, sand lance, sardine, sprat, bluefish and mackerel (Fromentin and Powers 2005, and references therein). Many of these species are found in the North Sea, in particular herring is currently very abundant (ICES, 2014). Often ABFT stomach contents are dominated by one or two locally abundant prey species, such as Atlantic herring and sand lance in the West Atlantic (Chase, 2002). So, high abundance of one or two pelagic or semi-pelagic/demersal (e.g. whiting) fish species should provide suitable prey for ABFT for the months that they are in the North Sea.

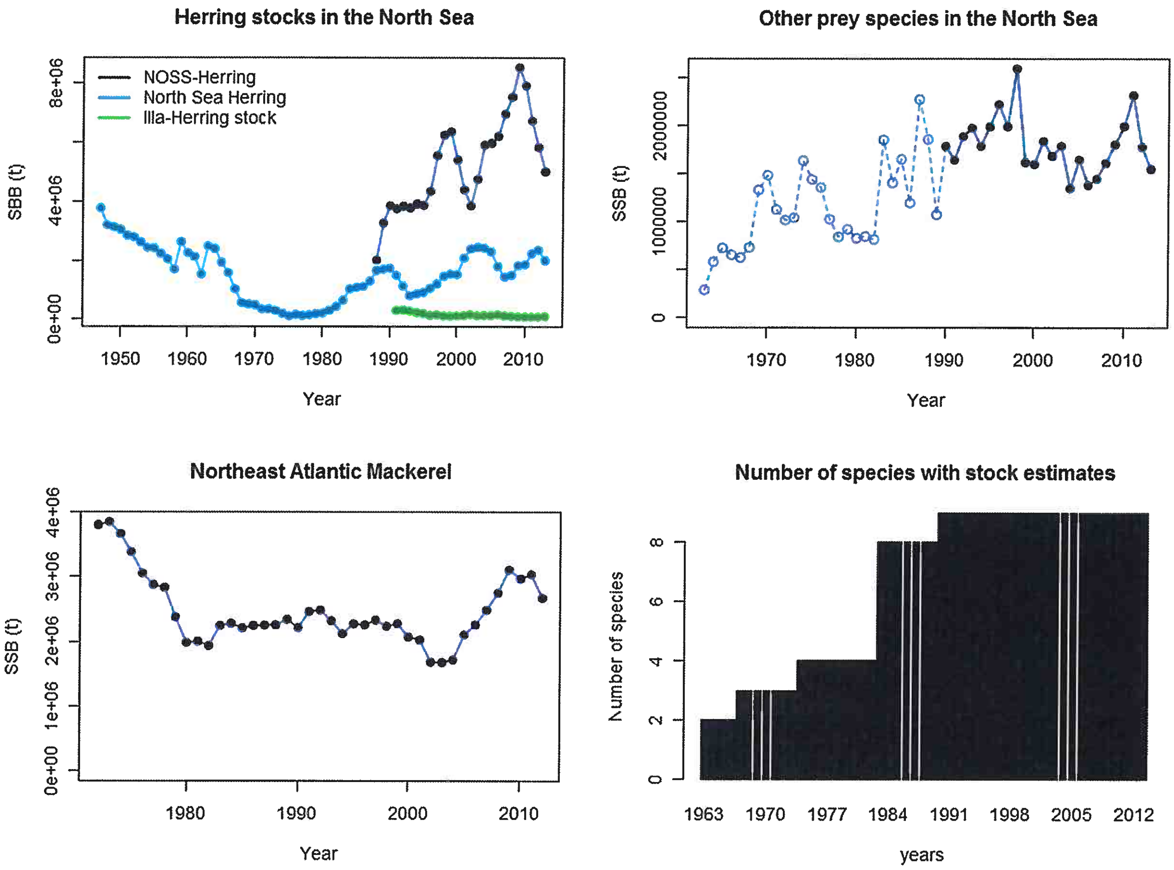
Data on the abundance and location of prey species have been collated and are presented in Figure 3.4. Unfortunately, most of the assessment model time series for species in the North Sea do not extend as far back in time as the 1940s or 1950s when ABFT was previously found in the North Sea. This makes comparison between current feeding conditions and previous feeding conditions difficult. Making conclusions on the trend in overall abundance is made difficult due to the different starting years of each assessment. Only since 1991 do all stocks considered have assessment results. So though there appears to have been an increase since the late 1960s, this is mainly due to the addition of new assessed species. Since 1991 the total SSB of other (excluding mackerel and herring) potential prey species for ABFT has fluctuated at a high level (between roughly 1.5 and 2 million tons) with no clear overall declining or increasing trend. These fluctuations are generally the results of fluctuations of recruitment of these species, since species such as sandeel, Norway out and haddock are noted for occasional large year classes that has a subsequent knock-on effect to SSB. North Sea autumn spawning herring has one of the longest time series available (ICES 2014) stretching back to the late 1940s. This stock collapsed at the end of the 1960s but since the 1990s has recovered to an abundant level and is likely to be a good source of prey for ABFT in the North Sea.

Herring are found nearly throughout the North Sea in the 3rd quarter (when ABFT are most likely to be in the North Sea) though adults are more abundant in the north west parts near the coast of Britain, and are mainly caught by fisheries in this area, and the juveniles (immature) fish are more commonly found in the south eastern regions of the coast of Denmark and Germany (Figure 3.5). Given that ABFT is a highly mobile species with individuals known to cross the Atlantic Ocean, it is not limited to searching for prey within a limited range and locating prey within the relatively smaller North Sea should not be a problem.

Mackerel is a another potential prey species that is currently very abundant (ICES 2013a). Most mackerel are located in the north east Atlantic outside of the North Sea, but in 2012 approximately one quarter of all landings were taken in ICES Subareas IV (North Sea) and IIIa (Kattegat and Skaggerak). Figure 3.6 shows the locations of mackerel landings in the 3rd quarter and survey results from the ecosystem survey of the Norwegian Sea and surrounding waters in 2013. Mackerel are still abundant in the survey hauls at the limits of the survey in the northern North Sea, an area of the North Sea that Bluefin tuna used to pass as they entered the North Sea. With increasing temperature, increases in mackerel fisheries have been observed in the North Sea (ICES 2013a).

Juvenile ABFT are known to feed of cephalopods such as squid. There is still a need for assessment models for establishing the cephalopod population levels, so at present abundance of this prey species cannot be properly estimated. However, anecdotal evidence from fishermen and scientific surveys of the

North Sea (see Table 4.1) suggest that abundance has been high recently. In 2012, the German IBTS survey got anomalously large CPUEs of squid in both the first and third quarter.



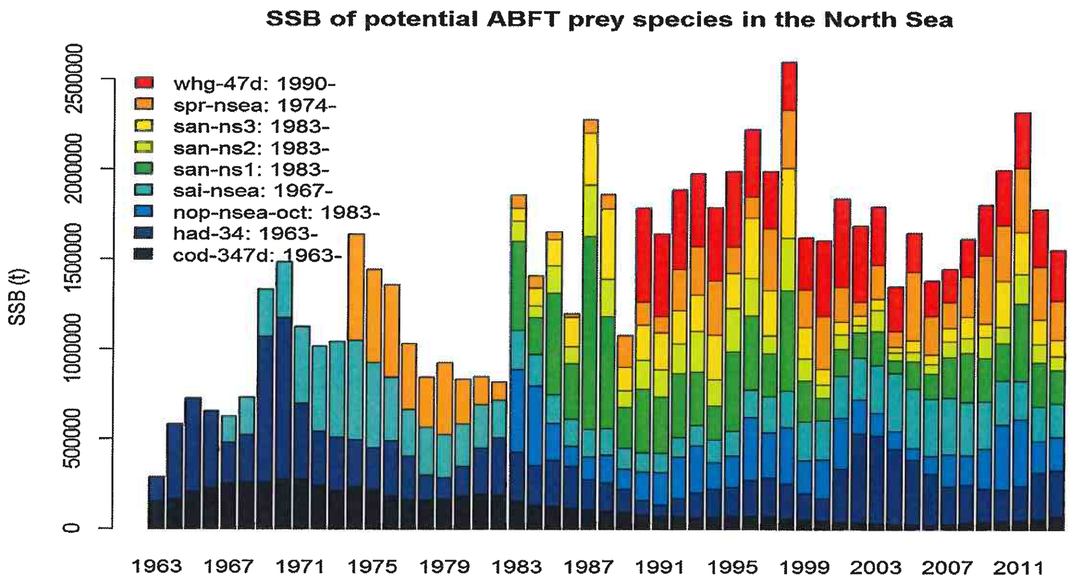


Figure 3.4. Spawning stock biomass of herring stocks (partly) located in the North Sea (top left), North East Atlantic mackerel (middle left), and other potential prey species for Atlantic Bluefin Tuna in the North Sea (top right, middle right and bottom), including, sprat (spr-nsea), norway pout (nop-nsea), sandeels (san-ns1-3) and gadoids whiting (whg-47d), saithe (sai-nsea), haddock (had-34) and cod (cod-347d). Note: Results are from the 2013 assessments of the stock, and not all time series begin in 1963. The first year of each time series is indicated in the legend.

Past reports have indicated that sightings of ABFT in the North Sea tended to be associated with certain fisheries (e.g. herring and mackerel; Le Gall 1927, Russell 1933a). This is not surprising since these are prey species of ABFT and sighting are generally made by the fishermen themselves. Likewise Walli et al (2009) ntoed that the regions of aggregation are associated with areas of abundant prey and potentially represent critical foraging habitats that have seasonally abundant prey. This indicates that these species used to play an important role as prey for ABFT at the time when they were in the North Sea. The current good status of herring and mackerel in particular should ensure that feeding conditions within the North Sea are currently very suitable for a species such as ABFT.

One concern that should be considered when releasing ABFT into the North Sea is the method of hunting used by the species. ABFT is a versatile predator as well as an opportunistic feeder. They are known to employ 'vigorous pursuit' when hunting small schooling fishes or squids, while 'modified filter-feeding' is (slow open-mouth feeding) used to feed on less agile organisms. Often ABFT school together with similar sized tuna and hunt by creating 'bait balls' (e.g. Clua and Grosvalet 2001). A bait ball occurs when small fish swarm in a tightly packed spherical formation around a common centre. A group of predators rapidly circle the fish school to compact it, then forage the periphery of the ball or lunge vertically through the centre of the ball as tuna are known to do. This type of predation requires a group effort from the predator and can likely not be performed by a single ABFT. However, Bluefin tuna are known to perform this type of feeding together with schools of dolphins, so multiple tuna may not be required for this type of feeding.

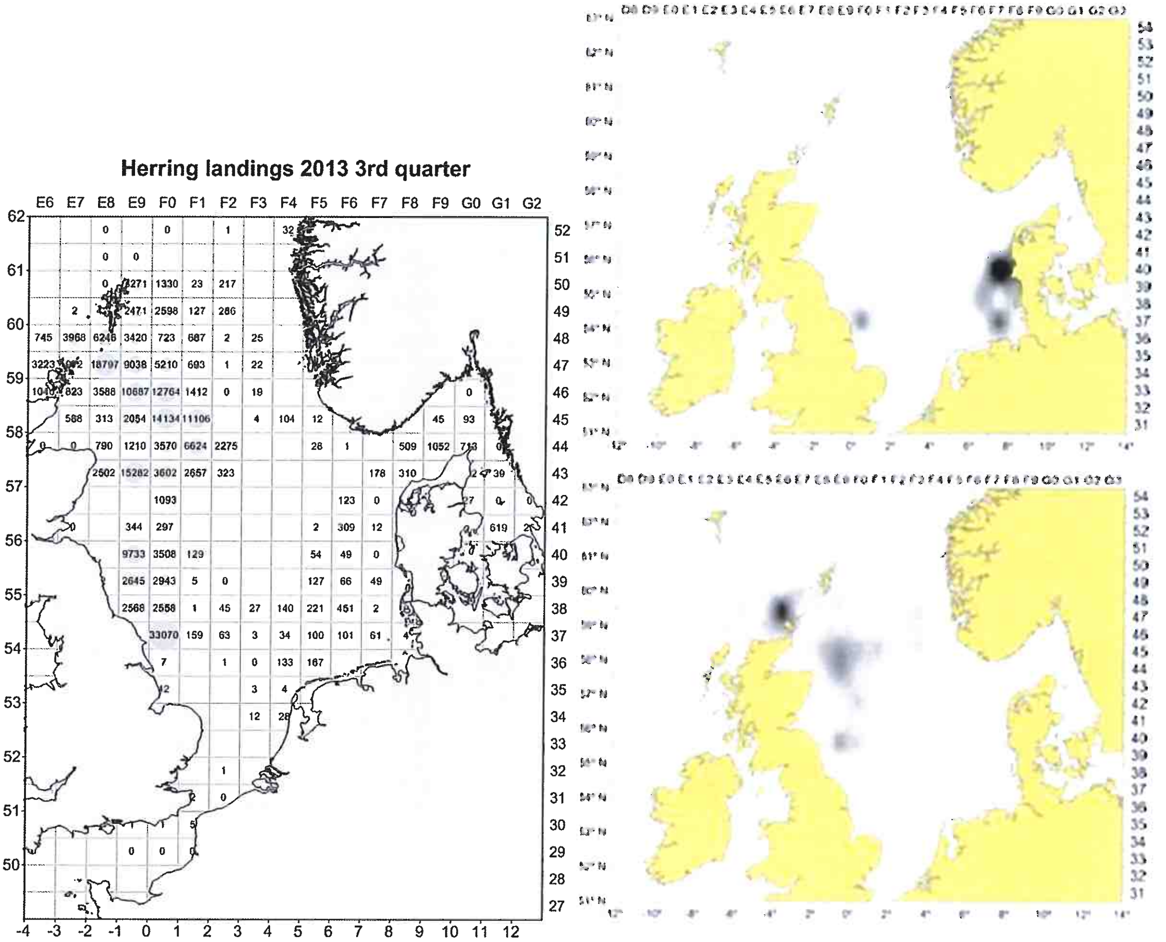


Figure 3.5. Herring landings in the North Sea in the 3rd quarter of 2013 (in tonnes) by statistical rectangle (left); biomass of immature (top right) and mature autumn spawning herring from the combined acoustic survey in June – July 2013 (source: ICES 2014a).

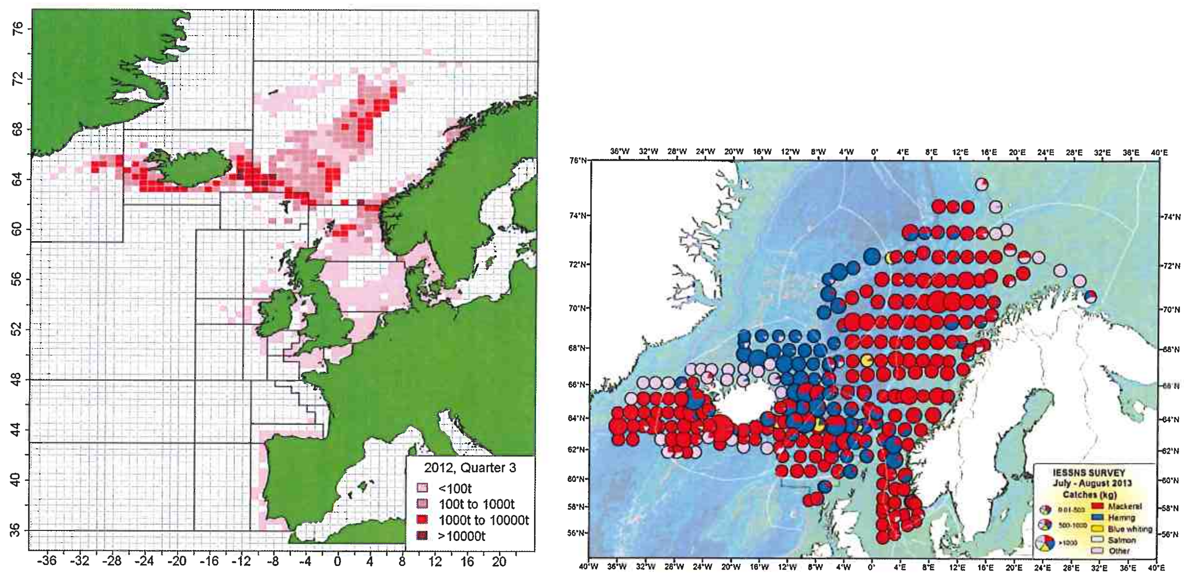


Figure 3.6. NE Atlantic Mackerel commercial catches in 2012, quarter 3 (left) and the distribution and spatial overlap between mackerel (red), herring (blue), blue whiting (yellow) and salmon (violet) from joint ecosystem surveys conducted in the Norwegian Sea and surrounding waters between 2nd of July and 9th of August 2013 (right) (Source: ICES 2013).

Table 3.1. Biomass Indices (kr/h) of the Germany North Sea IBTS from 2009 to 2012. Species here presented are that most common in the landings and species belonging to the same Family group (Source: ICES 2013).

		Quarter 1		Quarter 3	
	Year	Yield (kg/h)	S.E.	Yield (kg/h)	S.E.
Loligo spp	2011			0.04	0.03
Loligo forbesi	2009	0.43	0.15	0.41	0.36
	2010	0.99	0.37	0.11	0.05
	2011	0.28	0.10	0.29	0.13
	2012	28.46	0.00	6.06	0.50
Loligo vulgaris	2009	0.05	0.03	0.00	0.00
	2010	0.05	0.02		
	2011			0.08	0.07
	2012	0.17	0.00	0.66	0.20
Loliginidae	2009	0.47	0.18	0.41	0.36
	2010	0.99	0.37	0.11	0.05
	2011	0.28	0.10	0.41	0.23
	2012	7.50	0.00	4.15	0.64

3.2.2. *Potential threats to ABFT*

Given its size, speed, opportunistic feeding and position in the oceanic food web, there are few genuine threats to the survival of adult ABFT. The primary threat is from the directed fisheries on this stock (Laurie Kell, The International Commission for the Conservation of Atlantic Tunas, ICCAT, *pers. comm.*).

Fishing harvests

Global appetites for fish, especially Japanese appetite for sushi, has led to a growing global demand for tuna. The predominant gears used in the ABFT fishery are longlines, traps and bait boats for the east Atlantic, and purse-seine, longlines and traps in the Mediterranean (ICCAT, 2012).

The current TAC for all states/countries for all ABFT in Mediterranean and eastern Atlantic (east of 45° WL) is 13400t (EU TAC and quota regulations, Jaarboek Visserij 2013, bl. 434). Given the increase in stock abundance, fishing conditions in areas outside of the North Sea are currently good. Hence at present it is not likely that significant changes in fishing grounds would occur in the short term. However, this does not mean that in future if numbers in the North Sea reach high levels that fishing would not take place there. In 2013, Norway received permission to resume purse seine fisheries on ABFT in the Norwegian exclusive economic zone (EEZ) as from 2014.

Current management and enforcement of ABFT fisheries is considered to have improved compared to the past (ICCAT 2012). In general the North Sea in particular is a well regulated fishing ground in relation to areas where ABFT fishing currently occurs. As there are presently few ABFT in the North Sea, there is no commercial fishery on them. However, if they appear in the NS they will be regulated by this same quota system. However, certain individual countries (like the Netherlands) have forbidden a direct fishery on the species but allow a certain amount of bycatch to be landed (Jaarboek Visserij, 2013). Future management is not likely to change significantly so catches of ABFT in the North Sea should remain constrained by TACs.

Recreational fishing may be a relevant but unquantified source of fishing mortality on juvenile Bluefin Tuna (Collette et al 2013). When tuna was previously abundant in the North Sea areas such as Scarborough in the UK , regular reports of catches off the coast of England were made[1]. The overall impact of such fisheries compared to the commercial fisheries is likely to be low, but in an area such as the North Sea this could pose a potential threat to a released ABFT.

Bycatch of tuna is often problematic in longline fisheries targeting other tuna and large fish species. Bycatch from other fisheries (not longliners) is not generally considered to be a significant problem (Laurie Kell, The International Commission for the Conservation of Atlantic Tunas, ICCAT, *pers. comm.*). However, pelagic trawls and gill nets, which are known to have occasional porpoise bycatches, could also pose a threat to ABFT. Dutch pelagic freezer trawlers fishing for herring are mostly active in the central North Sea during Q3 (CVO rapport 13.013), so these could pose a potential threat. Purse seiners mainly target or bycatch ABFT when they are spawning. However, as the North sea is used as a feeding ground, this is probably not an issue in the North Sea. The ICES Working Group on Bycatch of Protected Species has not reported any bycatch of tuna in recent reports (ICES 2013b).

A number of other threats are considered relevant for ABFT over its whole distribution. However, not all of these apply to the North Sea. Such threats include:

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[1] Wikipedia contributors, " Big-game tunny fishing off Scarborough." Wikipedia, *The Free Encyclopedia*, http://en.wikipedia.org/wiki/Big-game_tunny_fishing_off_Scarborough (Accessed July 01, 2014)

Destruction, degradation or modification of critical habitat

The North Sea is not considered to be a critical habitat for this species. Alternative feeding grounds exist that do not necessitate the use of the North Sea as a feeding ground. ABFT have no link with specific habitat characteristics in the North Sea, other than the habitat characteristics required by their prey. Therefore habitat destruction, degradation is not a threat for their stay in the NS.

Lack of effective regulatory mechanisms protecting the species.

This applies largely to fisheries in the east Atlantic and Mediterranean regions. Comparatively speaking the North Sea has extensive regulatory mechanisms to protect species such as this and fishing effort in the North Sea is well controlled.

Disease

Incidences of disease are mainly linked to ranching operations, spreading from there to wild populations. This predominantly occurs in the Mediterranean, and no ranching operations exist in the North Sea.

Chemical Contaminants

As long-lived top predators, ABFT bioaccumulate and biomagnify contaminants e.g. Endocrine Disrupting Chemicals (EDCs) and mercury. However, most scientific studies of contaminants and tuna have focused on the effects on consumers rather than on the tunas themselves (Lowenstein et al. 2010, Vizzini et al. 2010). The North Sea does not pose a significant threat in this regard, certainly not in comparison to other areas of its distribution such as the Mediterranean.

Predation

Predators of tuna include marine mammals, including killer whales and pilot whales and some other large predatory fishes, and sharks (though usually this occurs once ABFT have been caught in longlines, Figure 3.7). Killer whales in Norwegian waters are observed to follow migration routes of the Norwegian spring-spawning herring stock (Simila et al., 1996). As ABFT is foraging on herring as well, they encounter these killer whales, while killer whale diets have been shown to include tuna and in the Mediterranean sea, killer whales have similar distribution patterns as ABFT (Jorgenson 1969, de Stephanis 2008).

The rather large size of adults drastically reduces the number of potential predator species. The tuna found in the North Sea were not young juveniles, adult ABFT should be more robust to this threat.

Figure 3.7. A shark attack on a captured bluefin tuna (Photo: NOAA).

Oil spills

There were concerns over the potential impacts on the 2010 western stock year class from the Deep Horizon oil spill that occurred in the Gulf of Mexico between April–August of that year (Campagna et al. 2011, Richards 2011). However, analyses ultimately showed that the overall population effect of even such a large oil spill disaster was considered to be low. The largest threat was found to be for larvae during spawning season. An analysis by the National Oceanic and Atmospheric Administration, using two different projections from computer models, says that at most, such a spill probably would result in a 4 percent reduction in future spawning of the fish, but probably far less. In addition, recent research has shown that Bluefin tuna may be susceptible to polyaromatic hydrocarbons, or PAHs, released in crude oil spills affecting heart functioning (Brette et al. 2014).

Though oil platforms are present in the North Sea, this area is not a spawning area for the stock and such events would likely lead to tuna departing the affected region.

Ocean traffic

The North Sea is a busy section of ocean with many transportation ship, ferries, fishing boats and other vessels. This is not considered to be a significant threat to fast swimming ABFT.

Underwater noise

Underwater noise, generated by construction and continuous functioning of windmills and traffic may impact on tuna behaviour. Additionally the effect of noise in the shallower North Sea, compared to the deeper Mediterranean and open Atlantic ocean may be different. No definitive studies exist on the likely impact of noise on ABFT, though a very sound polluted area may not be as attractive to this species if it is able to find sufficient food in a quieter location.

3. 3 Future

To be able to estimate whether the North Sea will stay suitable habitat for the ABFT, future changes should be taken into account. Climate change is known to change abiotic factors, like temperature and salinity. As all organisms have a range of acceptable environmental conditions, environmental changes could turn suitable habitats in non-suitable habitats. This situation is called a direct effect. However, indirect effects can occur as well. In those situations the organism itself can cope with the new environmental conditions, but predators or prey cannot, which in turn effect the organism. As prospects always include some uncertainty, the effects caused by the expected changes should be treated with some reticence. For indirect effects, this uncertainty is even higher.

Moreover, anthropogenic developments will probably affect the North Sea as well. With an increasing world population, pressure from mankind on the ocean is increasing. However, actual pressure is depending on the (social) vision on nature-management –which probably depends on economic developments in turn.

3.3.1 *Climate change: direct effects*

Multiple climate change scenarios exist, forecasting changes in abiotic factors up to 2100 (IPCC 2013, KNMI 2014). All scenarios predict an increase in surface temperature, with a minimum of 0.3 °C and a maximum of 4.8 °C. The likelihood of these scenarios is variable, and most scenarios focus on land instead of the ocean. Translation of these predictions towards changes in oceanic abiotic factors should therefore include some precaution. Predictions on other abiotic factors, like salinity, wind, precipitation and acidity have been made as well. However, accuracy of these predictions is even less then for temperature. In Table 3.2, the different expectations for several abiotic factors are shown. For comparison, the range of abiotic values observed for adult ABFT is shown as well. Historically, bluefin tuna inhabited the North Sea during spring and summer, exiting the system when temperatures fell below 12 °C (Tiews, 1978 in Fromentin and Powers, 2005). As ABFT is using the North Sea as a feeding habitat, and all predicted changes in abiotic factors are within ABFT-range, climate change is likely not leading to an intolerable environment.

Table 3.2. Present conditions in the North Sea and the forecasted changes in several abiotic factors, compared with the observed range of these factors for ABFT. NA= information not available.

Abiotic factor	Observed range in ABFT	North Sea present	North Sea expected
Temperature	2.8- 30 °C [1,2]	5-15 °C [3]	Increase: 0.3-4.0 °C [4,5]
Salinity	31 - 39 ‰ [1]	32-35 ‰ [3]	Decrease due to precipitation. [4]
Depth	0 - 1000 m [1,2]	**Southern Bight** (51-54 N): <40m; **Central North Sea** (54-57N): 40-100m; **Northern North Sea** (north of 57N): 100-700m	
Acidity (pH)	NA	7.5-8.5 [3]	Decrease: -0.2 - -0.4 [4]
Precipitation	NA	NA	Increase 10-20% [4]

1= Fromentin et al (2014); 2 = Block et al (2001); 3= Beare et al (2013); 4=IPCC (2013); 5=KNMI (2014)

3.3.2 *Climate change: indirect effects*

Indirect effects are hard to forecast, since not only the changes are not exactly known, the direct effects on the prey species are not a priori clear. Moreover, the adaptions of the ecosystem (food web) to the changes in prey species may "buffer" the total effect. A nice review of indirect effects can be found in van Hal (2011) (in Dutch) or in Rijnsdorp (2009).

The focus of this indirect effects-section will be on temperature increase, since this is the most certain aspect of climate change. With the predicted increase in temperature, prey distributions are likely to shift. Generally speaking, most temperature ranges are forecasted to shift a little north, as the northern parts are coldest. Cold water species, already living in the northern parts, may then move out and disappear from the North Sea. Tuna is a species which migrates over long distances, at a high speed. A possible shift in prey species distribution will therefore cause a shift in tuna distribution, and not cause any serious problems.

A shift in distribution of harbour porpoises was observed. Where in 1994 the majority of the population was observed in the northern North Sea, in 2005 the majority of the population was observed south of Edinburgh (Hammond et al (1995, 2002), SCANS (2008)). Like ABFT harbour porpoises predate on herring, but also on gadoids and sandeel. It is hypothesized that the distribution shift of the porpoises is caused by a decline in prey species in the northern North Sea. However, this hypothesis is not tested for (yet). And although sandeel have declined in 2004 in the northern parts (ICES 2013c), this is not observed in herring catch data (ICES 2012).

3.3.3 Anthropogenic development in the North Sea

Since immemorial times, humans have used the ocean as a resource and for transport. When methods to explore and exploit the ocean become more advanced, anthropogenic effects increase. Likewise, with the growing world population, pressure from mankind on the ocean is increasing. Nowadays, the North Sea is used in multiple ways, all with their own effects on the ecosystem. In van der Wal and Wiersinga (2011, in Dutch), the spatial usage of the North Sea is visualised and based on two economy-scenarios future developments are forecasted.

Current usages of the North Sea are: wind farms, oil and gas drilling (platforms and pipelines), transport, sand extraction, recreation, data-cables and fisheries. Depending on economic, social and technologic developments, these factors develop. In future, the spatial scale of wind farms, transport, sand extraction, recreation and data-cables are thought to increase, while the spatial scale of oil and gas drilling-systems and fisheries will likely decrease (van der Wal and Wiersinga (2011)). Moreover, offshore aquaculture might develop. Each factor has it individual effect on the ecosystem, and developments might alter these effects as well. For fisheries for instance, all new developments are about minimising the impact on the surroundings.

For all these usages of the North Sea, no direct threats can be distinguished for Bluefin tuna (no large bycatches and no run-overs by transport vessels). However, much of the effects of these usages on the ecosystem and individual species is unknown, and interacting effects might exist (no fisheries are allowed in wind farms). Most likely, the underwater noise produced by wind farms, oil and gas drilling stations and transport can constitute a problem (van der Wal and Wiersinga, 2011). ABFT is thought to be affected by underwater sounds (Rouyen et al., 2010), although the results of this study is correlational and in-directive. Therefore, it would be interested to further investigate the effects of underwater noise on (adult) ABFT.

4. Knowledge gaps

Atlantic Bluefin tuna is a well-studied species given its high value and current 'endangered' status. However, it is also a complex species to study given its broad geographical range. So little is currently known about environmental or biological factors impacting life history traits of bluefin, and other large pelagic species (albacore, swordfish and blue marlin) in the North Atlantic (Trenkel et al., 2014). Bluefin tuna in the North Atlantic has a complex population structure, common amongst such widely distributed and highly migratory species. Further investigations are ongoing to develop a greater understanding of the complex population structure of ABFT (ICCAT 2012).

In addition, other areas where knowledge is lacking include:

- Fishery independent information that can be used to develop fishery independent indices of abundance or mortality to better track trends in biomass and better estimate the impacts of fisheries on this species (ICCAT 2012). Such information could be obtained from large-scale tagging programmes or through aerial surveys, for example.
- Biological information (growth, ageing, maturity, reproduction), particularly differences between the eastern and western stocks requires further work.
- Research about the ABFT population structure.
- Research on the effects of noise on ABFT.
- Understanding triggers for migratory behavior (why, when and where) and how ABFT select appropriate feeding grounds in any given year.
- The effect of temperature on herring (and other prey species) distribution.
- The suitability of tuna for translocation experiments, including how they should be handled, the level of stress for tuna, the numbers that should be translocated and how likely such experiments would succeed.
- The navigation method used by tuna is still not fully understood.

5. Discussion

In the past (up to 1960s), the North Sea was a summer feeding ground for Atlantic Bluefin Tuna. Abiotic factors have not changed much since then, and are unlikely to change beyond the ranges suitable for ABFT in the near future. Herring, one of the key prey species in the North Sea is still abundant, and although shifts in distribution patterns might be expected in future, sufficient numbers are present for tuna. We conclude that the North Sea is and most likely stays suitable for ABFT, even though the North Sea is not a critical/essential habitat for ABFT. However, the rest of the northeastern Atlantic qualifies as suitable habitat as well.

5.1 Why not enter a suitable North Sea?

Since the North Sea was, is and will be suitable for ABFT, the question arose why no tuna are observed within the North Sea. Several reasons for this lack of observations can be hypothesized. Firstly, there might be a barrier (biotic or abiotic) which is preventing the ABFT from entering the North Sea, such as an increase in killer whale (*Orcinus orca*) population in the northeast North Sea predating on ABFT (Jorgenson 1969). Since population estimations of killer whales are not available for the 1950s, no population trend can be made. However, from whaling data between 1937-1968, it becomes clear that killer whales were present in the northeastern Atlantic, including the North Sea (Jorgenson 1969).

A second option for the non-abundance in the North Sea could be that the migration route towards the North Sea is not known within present ABFT populations. Historical fisheries data indicate that mostly adult individuals migrated towards the North Sea (Fromentin and Powers, 2005). Already in 1978, it was observed that after the decline of the ABFT population in the North Sea, the mean size of captured tuna increased (Tiews 1978). This suggests that the same year class continued to migrate into the North Sea, but that new year classes did not join. As ABFT is believed to perform "repeat homing behaviour", which essentially mean that habits are learned by copying adult behaviour (Fromentin and Powers 2005). As current ABFT have no experience with the North Sea migration route, they have no memory driving them towards it and might not know how to enter the North Sea, or indeed may not be aware of its existence as a potential feeding ground at all.

Finally, the ABFT populations have been reduced, which might reduce the need for another feeding area. Since the populations have recently started to increase again, the function as feeding areas for the North Sea may be naturally restored in future. However, at present there is sufficient prey species outside of the North Sea and it may be that there is no need for another feeding area.

This would depict natural processes of distribution shift have occurred and as no obvious barrier can be found, it should be assumed that ABFT itself opts to remain in other Atlantic feeding grounds rather choosing to search for an alternative feeding ground such as the North Sea. This raises the question why humans would "force" ABFT into the North Sea.

5.2 Translocation experiments

In literature, no translocation experiments could be found for ABFT; other fish species (primarily freshwater and anadromous species) have been subjected to translocation experiments (Crook 2004, Jessop 1976, Lintermans 2013). However, success rates of translocations studies vary (Lintermans 2013, Fisher 2000). Most studies are conducted to restore/reintroduce a population/species in an area it used to occur (Jessop 1976, Lintermans 2013, Fisher 2000). Also studies in homing behavior have used translocation experiments (Crook 2004). Since ABFT used the North Sea solely as a feeding area, homing behavior may ensure a safe return to the Mediterranean sea. However, navigation mechanisms in ABFT are not completely understood, and effects of translocations might cause unforeseen problems for ABFT navigation. Moreover, as homing behavior is focused on a safe return to the spawning grounds, rather than returns to potential feeding grounds, it cannot be expected that translocated ABFT will return to the North Sea in subsequent years.

Secondly, an extensive study to the successes and the possible improvements in performed translocation and reintroduction experiments stated that success of these experiments is depending on several factors (Fisher 2000). For instance, the number of released animals should be sufficient. In the article, they state a minimum of >100, however, this article included experiment with mammals as well, which may affect this number. Also the reason for decline of the original population should be removed to increase success probability and predators should not be around in the new area.

Considering these arguments, the feasibility of the proposed translocation experiments on ABFT in the North Sea can be discussed. As the cause for the decline in tuna remains unclear, this cause might still be in place. Moreover, killer whales -tuna predators- are abundant in the northern North Sea and Norwegian waters. Additionally, ABFT display schooling behavior and certain types of feeding behavior require a number of ABFT to work as a team. Further, the likelihood of the fish returning to the North Sea in subsequent years is likely to increase with the number of fish translocated. These arguments suggest that a translocation might not be successful. In addition to these arguments, there is much uncertainty in the implementation of the actual experiment. Assumptions should be made in the number of tunas involved and for the best location within the North Sea to place the translocated tuna.

6. Conclusion

IMARES was requested to perform an inventory of the suitability of the North Sea for Atlantic Bluefin tuna for WWF.. Based on an literature research, IMARES concludes that the North Sea was, is and probably will be a suitable feeding ground for ABFT. However, since no tunas are observed in the North Sea these days, there probably is some reason why ABFT is not entering the North Sea.

Together with varying results of previous translocation experiments on other species and knowledge gaps in life history, migration and navigation mechanisms of tuna, this raises the question whether the performance of a translocation experiment on ABFT in the North Sea would be wise. No previous scientific support for such an experiment can be found.

7. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Non-scientific reading list

General

Atlantic Bluefin tuna is a commonly listed species in many conservations and management group species of concern. E.g.:
WWF
http://www.worldwildlife.org/species/bluefin-tuna
FAO
http://www.fao.org/fishery/species/3296/en
Encyclopedia of life: various bits of information and literature refs.
http://eol.org/pages/223943/details
Animal diversity web
http://animaldiversity.ummz.umich.edu/accounts/Thunnus_thynnus/

History in the North Sea
History in North Sea (article about MacKenzie paper):
http://phys.org/news105536834.html
Good summary article of the history of British fishery (not all North Sea):
http://www.worldseafishing.com/features/history-british-tuna-fishery/
History of Norwegian fishery:
http://www.northseatrail.org/show_single_article.php?article_id=6&lang=dk

Present observations
Reports of catches off UK:
http://www.glaucus.org.uk/Tunny.htm

Catch off hebrides:
http://www.hebrides-news.com/hebridean_bluefin_tuna_caught_26913.html

Fishing off Scarborough
http://en.wikipedia.org/wiki/Big-game_tunny_fishing_off_Scarborough

North of Ireland:
http://www.independent.co.uk/news/uk/this-britain/novice-catches-britains-biggest-fish-for-50-years-698659.html

Threats
IUCN redlist:
http://www.iucnredlist.org/details/21860/0

Illegal fishing:
http://www.fishupdate.com/news/fullstory.php/aid/21183/Shocking_illegal_tuna_figures.html

Bycatch petition (western Atlantic):
http://advocacy.pewenvironment.org/ea-action/action?ea.client.id=1793&ea.campaign.id=22509&ea.tracking.id=Web

FAO tuna longlinging
http://www.fao.org/fishery/fishtech/1010/en

Huffington post NOAA bycatch report:
http://www.huffingtonpost.com/2013/06/19/bluefin-tuna-population_n_3468240.html

Justification

Report C174/14

Project Number: 4301107201-Bluefin Tuna

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Ir. R. van Hal
Researcher

Signature:

Date: 16th of December 2014

Approved: Dr. ir. N.A. Steins
Head department Fisheries

Signature:

Date: 16th of December 2014