Northwest Atlantic tuna: Identification and size conversion

by:

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SUMMARY

Clay, D. and T. Hurlbut. 1991. Northwest Atlantic tuna: Identification and size conversion. Can. Tech. Rep. Fish. Aquat. Sci. No. 1820:49 +iv p.

Identification of semi-processed Atlantic bluefin tuna (Thunnus thynnus thynnus (L.)) is a difficulty faced by the Department of Fisheries and Oceans. This problem exists because high prices and reduced catch allocations have combined to increase the incentive to misreport regulated tuna species. Routine taxonomic keys are often inadequate for 'legally' accepted identification of semi-processed bluefin tuna. Indirect identification by size and both external and internal characters are described.

Since about 1983 Canadian sampling of Atlantic bluefin from the inshore fisheries has been limited to the collection of the individual weight of each tuna landed. These data are used as input to the analytical assessment conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT). They must first be converted from weight to length before use as a part of the catch at length data necessary for the ICCAT assessments. Conversion factors for measurements of dressed to live bluefin are provided from the sampling program of the offshore longline fisheries. The conversion of 'late season' dressed tuna to round weight is about 1.15 with a range of monthly values for September to February from 1.12 to 1.16. The early season (July and August) conversion factor is nearly 1.22.

Seasonal length weight relationships of bluefin and other tuna species caught within the Canadian EEZ are provided from both data of the inshore and offshore fisheries. The coefficients of determination (r^2) of the seasonal relationships vary dependent upon the range of tuna sizes in the analysis. They do indicate strong relationships with limited overall variation.

RESUME

Clay, D. and T. Hurlbut 1991. Northwest Atlantic tuna: Identification and size conversion. Can. Tech. Rep. Fish. Aquat. Sci. No. 1820:49 +iv p.

Le ministère des Pêches et Océans exige que le thon rouge (Thunnus thynnus thynnus (L.)) semi-transformé soit identifié. Les prix élevés conjugués à une diminution de l'allocation des prises ont favorisé les fausses déclarations à l'égard des espèces de thon couvertes par la réglementation. Les clefs taxinomiques habituelles ne permettent souvent pas d'identifier de façon "légalement reconnue" le thon rouge semi-transformé. Le présent rapport décrit le processus d'identification indirecte par la taille et des caractères externes et internes.

Au Canada, les activités d'échantillonnage des prises côtières de thon rouge se sont limitées à la collecte de données sur le poids de chaque thon rouge débarqué depuis 1983. La Commission internationale pour la conservation des thonidés de l'Atlantique (CICTA) se sert de ces données à des fins d'évaluation et d'analyse. Les données sur le poids doivent tout d'abord être transformées en données sur la longueur avant de pouvoir servir à déterminer les données sur les longueurs des prises dont la CICTA a besoin pour effectuer ses évaluations. Le rapport présente les facteurs de conversion du programme d'échantillonnage des prises hauturières à la palangre permettant d'obtenir les mesures d'un poisson vivant à partir d'un poisson habillé. Le facteur de conversion du poids d'un thon habillé "de fin de saison" en poids brut est d'environ 1.15, les valeurs mensuelles variant de 1.12 à 1.16, de septembre à février.

Le rapport présente également les saisonnières de la relation longueur/poids du thon rouge et autres thonidés capturés dans la ZEE du Canada, tant près des cêtes qu'en haute mer. Les coefficients de détermination (r^2) des relations saisonnières varient selon la gamme de tailles analysée, mais révèlent que les relations sont fortes et varient peu dans l'ensemble.

ACKNOWLEDGEMENTS

The Department of Fisheries and Oceans (DFO) International Observer Programs in St. John's, Newfoundland (Dave Kulka) and Halifax, Nova Scotia (Mark Showell) have cooperated in the provision of the data used for the ICCAT Task I and Task II statistics for many years. In 1989, following a special request, they arranged for the collection of the dressed length and dressed weight data used for this analysis. The authors would like to thank them for their continued assistance over the years.

Some data used in this analysis were collected between 1955 and 1975 (before the authors arrived on the scene) by various staff of the departments then responsible for marine fisheries. These data were obtained from the 'archive' files of the St. Andrews Biological Station. We wish to thank all the persons involved in this early data collection - - these include but are not limited to: Messrs Noel Tibbo, the late Lou Day, Jim Beckett, Clayton Dixon, and Ms. 'Billie' Burnett.

We would like to thank Jim Beckett (DFO, Ottawa), David Cairns, Simon Courtney, and Mark Hanson (all of DFO, Moncton) for their reviews and helpful critiques of this document.

The Food and Agriculture Organization of the United Nations has kindly permitted the use of several drawings and art work from 'FAO Fisheries Synopsis 125, Vol. 2: FAO Species Catalogue: Scombrids of the World' by Collette and Nauen (1983). Dr. B. Scott kindly permitted the use of the key for Scombrids of Canadian Atlantic Waters (Scott and Scott, 1988).

I. INTRODUCTION

Atlantic bluefin tuna (Thunnus thynnus thynnus (L., 1758)) have been harvested in Canadian waters since the turn of the century. Until recently the fishery supported only recreational fishing and a low value institutional and pet food industry. This changed in the early 1970's with the introduction of Canadian bluefin to the Japanese sashimi market. This was made possible by the advent of high volume rapid air transport to Japan. The value of these fish increased from a few cents to many dollars a pound.

With this higher value market came demands for a better quality product. As a result, during the 1980's many quality control improvements have been introduced. In the early 1980's, bluefin caught in the Gulf of St. Lawrence rod and reel fishery and the St. Margarets Bay trap fishery, were usually bled at sea (by severing the caudal artery) and then towed to shore for processing. Later in the mid-1980's, attempts were made to encourage fishermen in the Gulf of St. Lawrence to transport the bled fish to processing plants in ice filled containers. The latter technique was never widely practiced due to the difficulty of placing these large fish (> 400 kg) into tanks aboard the relatively small vessels (< 13 m). Nevertheless, the proximity of the fishing grounds to the processing plants meant that good quality could still be achieved because the fish could be butchered on shore and placed in icewater within a few hours. Unfortunately, few round weight or fork length measurements were recorded due to the speed with which this was completed.

The bluefin tuna is a migratory species that spawns in the Gulf of Mexico in spring (Richards, MS 1990) and completes an annual seasonal feeding migration to the rich feeding grounds of the northwest Atlantic in summer and autumn (Clay and Hurlbut, 1986). Some individuals even migrate across the Atlantic to European coastal seas (Mather, 1962; Suzuki, MS 1990). The present view of stock structure is that there are stocks in the eastern and western Atlantic with limited intermixing (see Clay (MS 1990) for review of current assessment interpretation). This premise is used in the analytical assessments conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT).

The western stock was heavily exploited in the 1960's and 1970's and subsequently declined throughout that period, the 1980's and into the 1990's. The first catch restrictions were recommended for the western stock by ICCAT in 1982 (Anon, 1985). The implementation of these catch limitations in association with increasing prices has increased the incentive for misreporting. Because bluefin is the only regulated tuna species in 1991 in the Canadian Exclusive Economic Zone (EEZ), some fishermen have attempted to report semi-processed bluefin as one of the less valuable non-regulated species. The most common substitution attempted is with bigeye tuna (Thunnus obesus (Lowe, 1839)).

This report was prepared to fulfill two objectives. The first objective is to review the literature and analyse historic Canadian data pertenant to the identification of bluefin tuna, especially when sampled in a dressed condition.

The second objective is to provide a more accurate series of size conversion factors. After converting dressed weights to equivalent live weights, a seasonal weight to length relationship is required to convert the weight based sampling conducted by the Department of Fisheries and Oceans (DFO) to length frequencies for the annual analytical assessment.

This report describes the criteria required to identify the various species of tuna fished in the northwest Atlantic and provides factors to convert available measurements to the statistical data needed for stock assessment.

II. TUNA IDENTIFICATION

Tuna are predacious fish found in the warm upper layers of the oceans, some are considered sub-surface, however even these are rarely found below 200 m. Bluefin and albacore (Thunnus alalunga (Bonnaterre, 1788)) are considered temperate species and found well north (or south) of the more tropical species (Laevastu and Rosa, Jr., 1963).

Tribe Thunnini

The family Scombridae (Figure 1) includes the "true tunas" (tribe: Thunnini), the bonitos (tribe: Sardini), the Spanish mackerels (tribe: Scomberomorini), the mackerels (tribe: Scombrini) and the butterfly kingfish, (separate subfamily: Gasterochismatinae).

The thirteen species of true tunas, within the tribe Thunnini (Figure 2), include many species that do not occur or occur only rarely in eastern Canadian waters

Figure 1. The worldwide family Scombridae or mackerels and its 15 constituent genera (48 species) (after Collette and Nauen, 1983).

FAMILY	SUB-FAMILY	TRIBE	GENUS	No. of species
SCOMBRIDAE	SCOMBRINAE	Tunas (Thunnini)	Thunnus	(7)
			Katsuwonus	(1)
			Euthynnus	(3)
			Auxis	(2)
		Bonitos (Sardini)	Allothunnus	(1)
			Gymnosarda	(1)
			Sarda	(4)
			Cybiosarda	(1)
			Orcynopsis	(1)
		Spanish mackerels (Scomberomorini)	Acanthocybium	(1)
			Scoberomorus	(18)
			Grammatorcynus	(1)
		Mackerels (Scombrini)	Rastrelliger	(3)
			Scomber	(3)
	GASTEROCHISMATINAE		Gasterochisma	(1)

(ie. the blackfin tuna (Thunnus atlanticus (Lesson, 1830)), the "kawakawa" (Euthynnus affinis (Cantor, 1849)) and the little "tunny" (Euthynnus alletteratus (Rafinesque, 1810)). The seven species of true tunas that have been reported from Canadian waters of the northwest Atlantic include: the Atlantic bluefin tuna, the bigeye tuna, the yellowfin tuna (Thunnus albacares (Bonnaterre,1788)), the albacore tuna, the blackfin tuna, the skipjack tuna (Katsuwonus pelamis (L., 1758) and the little tunny.

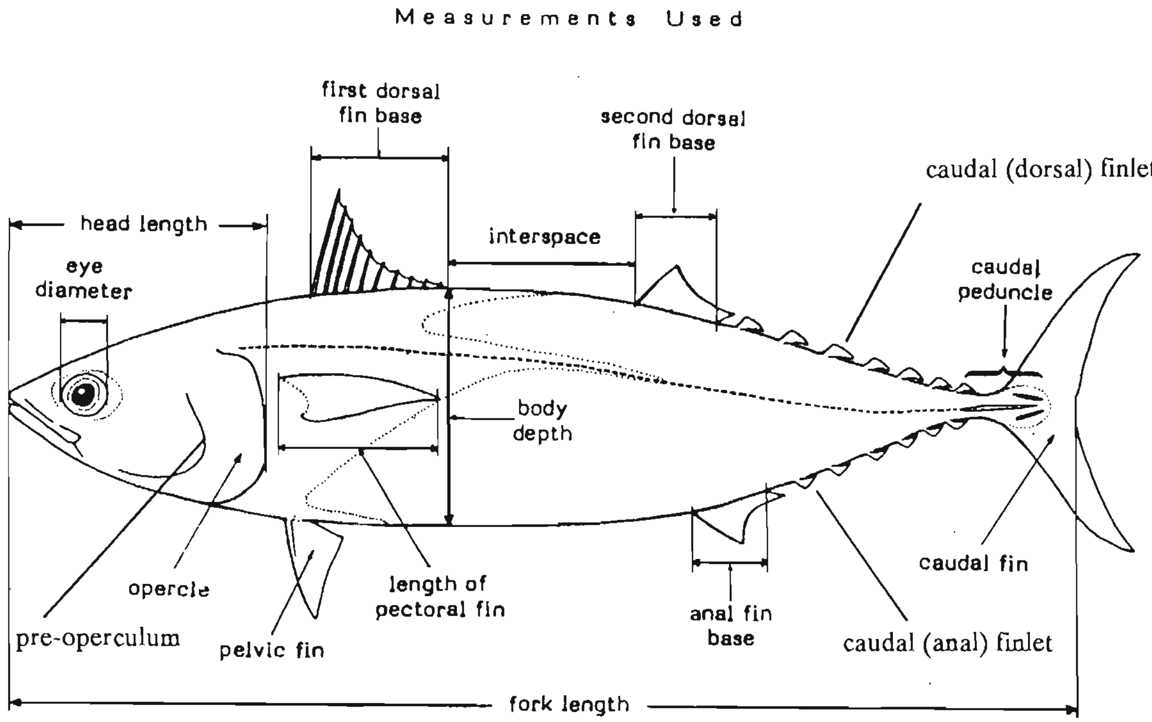
All true tunas of the tribe Thunnini share certain features (Figure 3). The body is nearly round in cross section, and is elongate and fusiform (torpedo-shaped) in profile. The first dorsal fin is high in the front and tends to sweep down in a concave curve to the posterior. The second dorsal fin and the anal fin are similar in size and shape, and each has a prominent lobe. In the case of the yellowfin tuna, these lobes may be >20% of body length. These fins are followed by a number of small finlets along the caudal peduncle (the narrowest part of the body just ahead of the caudal fin). On either side of the caudal peduncle there is a strong lateral keel (Figure 3) that is supported by a well-developed bony extension of the vertebrae. This median lateral keel is followed by a pair of obliquely oriented smaller keels at the base of the caudal fin (Figure 3). Some tunas, particularly the smaller species such as the skipjack and little tunny, have distinctive markings. Large tunas tend to lack distinctive markings other than the whitish spots on the bellies of some species.

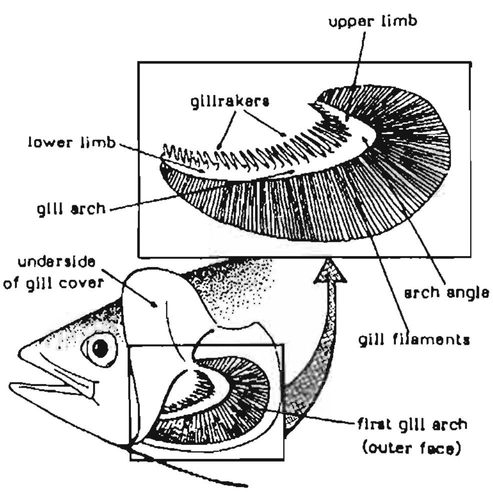
Similarities, which may be pronounced in the juvenile phases of some species, can lead to difficulties in identification. The colour and weight of tunas can vary within areas and seasons. Other characters used for identification such as eye size, body proportions, length and positions of fins vary with the size and age of fish but can, at times, be diagnostic. Specimens of some tuna species can be identified solely by size. However, identification of young tunas can be extremely difficult outside of a laboratory because some external

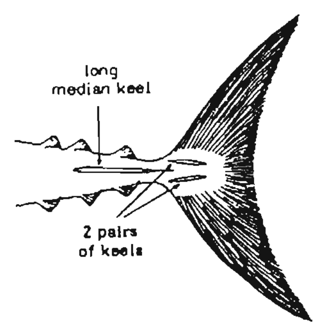
Figure 2. The tribe Thunnini of the family Scombridae (Figure 1). Outline sketches are provided for those species commonly found in the Canadian EEZ in Appendix III. Species commonly found within the Canadian EEZ are indicated by ** while rare occurences are indicated by *.

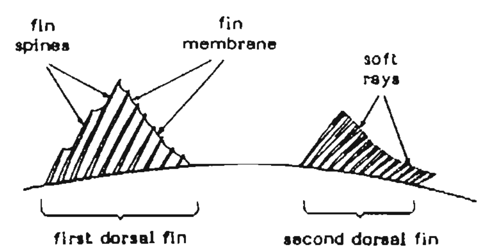
TRIBE	GENUS	SPECIES	(Can EEZ)
Thunnini	Thunnus	T. thynnus	(**)
		T. obesus	(**)
		T. albacares	(**)
		T. alalunga	(**)
		T. atlanticus	(*)
		T. maccoyii	
		T. tonggol	
	Katsuwonus	K. pelamis	(*)
	Euthynnus	E. lineatus	
		E. affinus	
		E. alletteratus	(*)
	Auxis	A. rocheri	(*)
		A. thazard	

Figure 3. Anatomical characteristics and typical measurements taken during morphometric studies of tuna (modified after Collette and Nauen, 1983). See Appendix II for definitions of some specific terms.









distinguishing characteristics do not appear until late in life. The identification of adults often depends on a combination of characteristics. For example, adult yellowfin have more yellow coloration on their body and fins than any other species but all tunas have some yellow on their fins. As a result, other characteristics need to be examined to ensure correct identification.

Alternate Forms of Identification

A common tendency when identifying an unknown fish is to compare its appearance with the illustrations or photographs in a current taxonomic reference book. This method, while useful in some cases, can lead to errors in identification.

The use of taxonomic keys for fish identification is the only reliable method of preventing misleading identification. With this method, the specimen to be identified is methodically "run" through the key(s), and the description is checked character by character, until the identification is completed. A sample 'tuna' key from Scott and Scott (1988) is provided in Appendix I.

The descriptions and figures in this report are provided strictly as a supplement to the more detailed taxonomic keys. This identification supplement is arranged into three sections to facilitate the hierarchical identification of specimens based on:

1. size,
2. external characters, and
3. internal characters.

A description is provided of the weight and length that would permit positive identification of certain specimens by their size alone. In this case, identification would not require examination of external or internal characters, however these latter examinations are encouraged.

Species identification is compromised when specimens are not in a whole, round condition (ie. when they are dressed or mutilated in some way). Depending on the amount of processing, some specimens can still be identified by examination of external characters, however the procedure is usually more complicated and requires examination of more characters.

The following descriptions and figures will aid in the identification of the various species of tuna that may be caught in Canadian Atlantic waters. However, if difficulties are still encountered and especially if juveniles are caught, the specimens can be forwarded to either: Science Branch, DFO, Moncton, N.B. or the Atlantic Reference Centre, Huntsman Marine Laboratory, St. Andrews, N.B.

Tuna Identification Based on Size

Occasionally it is possible to identify a tuna specimen (in the round or dressed condition) based solely on its weight or length and knowledge of:

1. the maximum recorded weights and lengths for the various species known to occur locally (Table 1 and Figure 4), and
2. local conversion factors from dressed to round weight or length for dressed specimens.

Then, depending on the size (actual or estimated round weight or length) of the specimen or carcass, some or most of the species known to occur locally can be ruled out.

For example, a carcass or whole specimen weighing 250 kg (550 lbs) or more can be confidently identified as a bluefin tuna because the maximum recorded round weight for any of the other species known to occur locally does not exceed 197 kg (the current world record size for a bigeye tuna in the Pacific Ocean). The same sort of process can be followed if only the length of a specimen or carcass is available.

Considering size alone, a specimen with a round weight of 159 kg (350 lbs), could be one of: yellowfin, bigeye, or bluefin. In this case definitive identification requires examination of external and/or internal characters.

The credibility of identifications based on size alone diminishes as the size of the specimen or carcass approaches the size of the next largest tuna species known to occur locally (ie. bigeye tuna in the case of bluefin). When this occurs, it is necessary to examine external and possibly internal characters to positively identify the specimen. It should be remembered that the maximum sizes recorded in Table 1 represent the sizes attained and approached by an extremely small percentage of individuals of that species (ie. although the maximum recorded size for bluefin tuna is 679 kg (1,496 lbs) there have been no more than 2 or 3 other bluefin landed with weights in excess of 636 kg (1,400 lbs)).

Figure 4. Maximum recorded weight and corresponding length of tuna found in the northwest Atlantic (Table 1). The solid bar within the species box indicates common range of sizes found and the three arrows indicate average sizes recorded in the 1989/90 Canadian bluefin fisheries. Codeing used for tuna species on X-axis: BFT - bluefin tuna; BET - bigeye tuna; YFT - yellowfin tuna; ALB - albacore tuna; SKJ - skipjack tuna; LTA - little tuna.

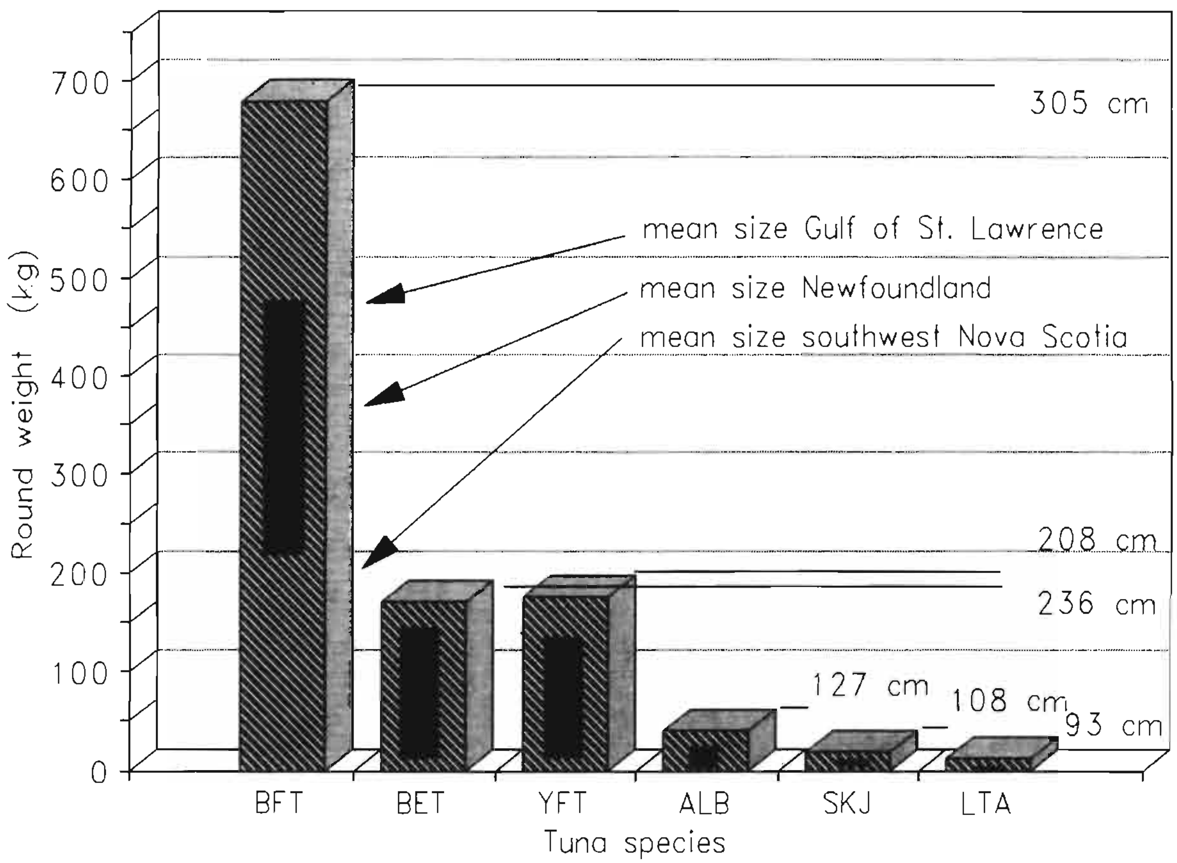


Table 1. **Maximum individual weight recorded (worldwide) for the six tuna species known to occur in eastern Canadian waters with their corresponding fork lengths.**

Species (Scientific Name)	Maximum Recorded Round Weight	Corresponding* Fork Length
Atlantic Bluefin (Thunnus thynnus thynnus)	Max. 679 kg (1,496 lbs) Common 200-450 kg in the northwest Atlantic	305 cm Common 200-275 cm in the northwest Atlantic
Bigeye (Thunnus obesus)	Max. 170 kg (375 lbs) in the Atlantic Max. 197 kg (435 lb) in the Pacific	Approx. 236 cm Common 40-170 cm (throughout its range)
Yellowfin (Thunnus albacares)	Max. 176 kg (388 lbs)	208 cm Common 40-150 cm (throughout its range)
Albacore (Thunnus alalunga)	Max. 40 kg (88 lbs)	127 cm Common 40-110 cm (throughout its range)
Skipjack (Katsuwonus pelamis)	Max. 18.9 kg (42 lbs)	Approx. 108 cm Common to 80 cm (throughout its range)
Little tunny (Euthynnus alletteratus)	Max. 12.2 kg (27 lbs)	93 cm Common 30-80 cm (throughout its range)

* - these lengths are not necessarily the maximum lengths recorded for each species.

Sources: International Game Fish Association (1987)
Collette and Nauen (1983)

Tuna Identification Based on External Characters

The identification of tuna species can be difficult, especially in the smaller range of sizes at which tunas of all species look similar (Mather, 1962a). Fortunately, the various species develop distinctive characters that facilitate unambiguous identification as they grow to lengths over 60 to 70 cm (about 1 to 2 years of age for bluefin tuna).

Allometric growth refers to the tendency for different parts of the body to grow at different rates as an animal develops. Tunas of the same species usually differ greatly in appearance at different sizes because of allometric growth and changes in colour patterns with growth. Failure to consider these changes with growth can lead to confusion.

The individuals of the six tuna species known to occur in Atlantic Canada tend to be sexually mature adults, with external characters that will not change significantly with further growth.

The three types of external characters that can be observed on a fish specimen are:

a. morphometrics (the measurement of different body proportions),
b. meristics (the counts of different body parts), and
c. colour patterns.

All three character types are useful to varying degrees for tuna identification; however, unequivocal identification frequently requires a combination of these characters and possibly size information and/or examination of internal characters.

Before attempting to identify tuna specimens using external characters, a brief review of the external anatomy of tuna is in order as well as familiarization with some standard fish measurements. Diagrammatic sketches of some of the anatomical characteristics of tunas and some standard morphometric measurements are shown in Figure 3. Definitions of each of the morphometric measurements are provided in Appendix II. A modified description from Collette and Nauen (1983) of each of the tuna species known to occur in Canadian Atlantic waters has been reproduced in Appendix III.

a. Morphometrics: Measurement of Body Proportions

Of the many morphometric measurements that can be made, the length of the pectoral fin (Figure 3) is one of the most important measurements available for separating tunas of the genus Thunnus (ie. bluefin, bigeye, yellowfin and the albacore - Appendix IV). This character is usually expressed as a proportion of the head or fork length but the position of the tip of this fin relative to specific anatomical "landmarks" (ie. 2^{nd} dorsal fin - Appendix IV) can also be determined.

The long pectoral fin of the albacore (usually 30 % of fork length or longer, reaching well beyond the origin of the second dorsal fin usually to the second dorsal finlet) separates it from all the other species. Likewise, the short pectoral fin of the bluefin (usually no more than 16.8 to 21.7 % of fork length (Appendix IV; Figure 5), never reaching the 'interspace' between the two dorsal fins) separates it from the other species in most instances. However, occasionally the length range of this fin may overlap in large specimens of bigeye and comparable sized specimens of bluefin (in bigeye greater than 110 cm fork length, the pectoral fin is usually 22 to 31 % of fork length).

When not removed or damaged, the pectoral fin should permit unambiguous identification of the carcasses of albacore tuna. This character may also contribute to the identification of bluefin carcasses with dressed weights in the range of 160 to 180 kg (ie. those sizes that potentially overlap the range for bigeye), but the reservations mentioned above should be borne in mind. It has been observed on many specimens that even after removal the pectoral fins leave a 'shadow' on the fish. Although not as accurate as measuring the actual fin, this can provide an estimate of the minimum pectoral fin size.

The allometric development of the second dorsal and anal fins in the yellowfin is much more pronounced than in other species. These fins on yellowfin (over 125 cm long) are well over 20 % of fork length, this easily separates them from the other tuna species (ie. bluefin where these fins can range from 10 to 15 % of the fork length (Figure 6)). Such allometry often leads to curvilinear relationships between body part (fin size) and fish length, although in some instances, depending on the size range of fish sampled, the relationship may appear linear. Because of this, we have provided regression equations of both transformed data (curvilinear) and untransformed (linear) data. Suspected anomalies among giant bluefin from the east

Figure 5. Pectoral fin length and fork length of 215 bluefin tuna from the western Atlantic. These fish were sampled between 1963 and 1973 in the months June to October. The horizontal bar indicates the size range Mather (1962) considered to exhibit isometric growth. The same data is presented as both the pectoral fin length and as a percent of fork length.

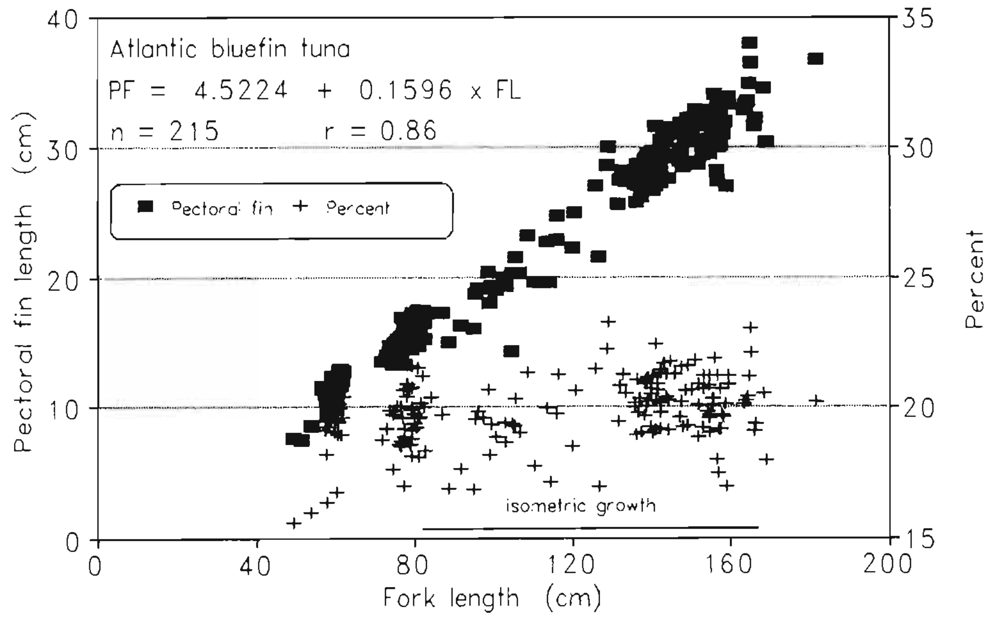


Figure 6. Dorsal fin length and fork length of 39 (1st dorsal fin) and 39 (2nd dorsal fin) bluefin tuna from the western Atlantic. These fish were sampled between 1963 and 1973 in the months June to October. Equations for both linear and log transformed data are presented.

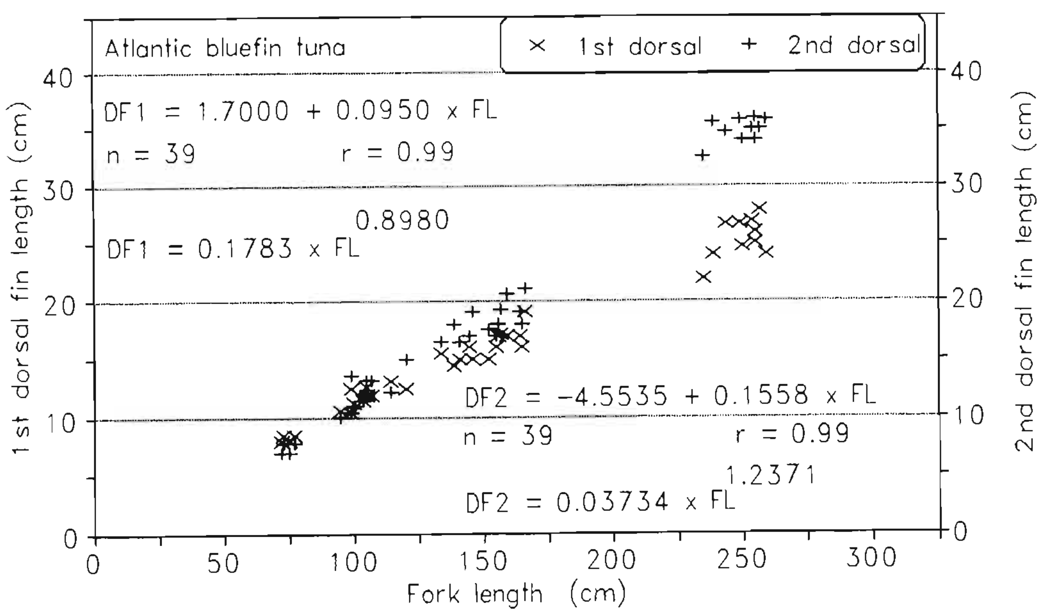
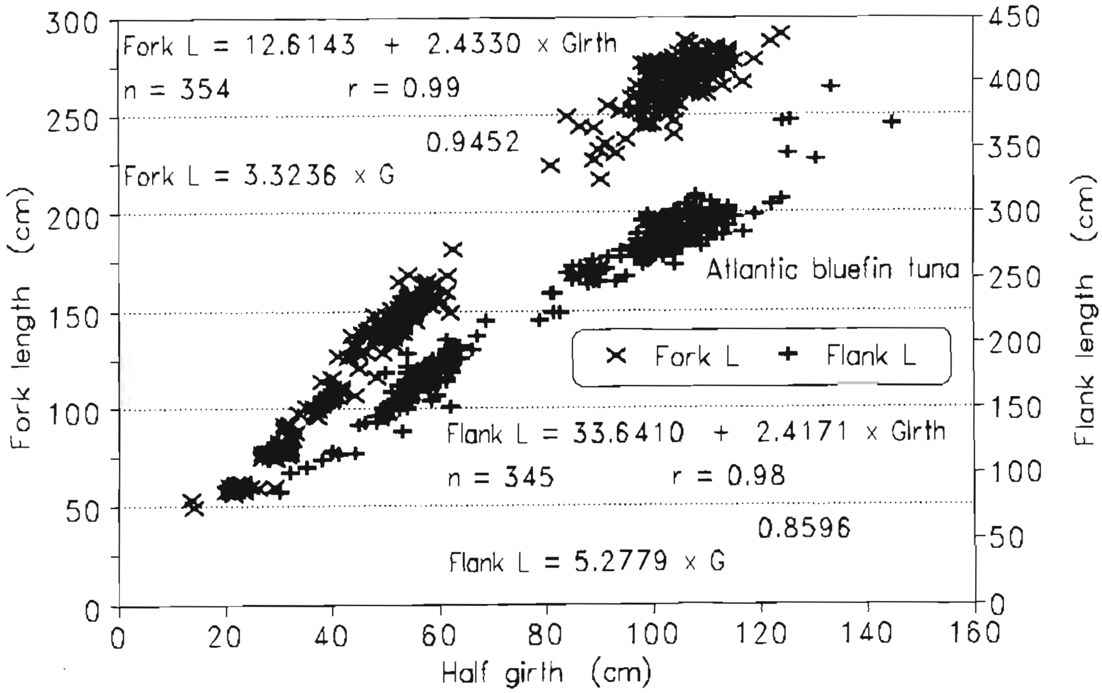


Figure 7. Half girth and length of 354 (fork length) and 345 (flank length) bluefin tuna from the western Atlantic. These fish were sampled between 1963 and 1973 in the months June to October. Flank length is a curved length measurement which follows the body shape - generally taken with a flexible 'tape measure'. Equations for both linear and log transformed data are presented.



and west Atlantic in 1974 were due to this allometry of the second dorsal fin (Schuck, 1975).

Maximum body depth (a 'straight line' measurement usually made with calipers) and the location of the maximum body depth is also considered of some value in tuna identification. Mather (1962a) considered that although maximum body depth can be variable among tunas of the same species, and notable seasonal differences have been observed in bluefin, it was still of some value in tuna identification. Bluefin, bigeye and yellowfin are deepest near the middle of the base of their first dorsal fin. In contrast, albacore are deepest at or slightly anterior to the second dorsal fin. Depth in bluefin and bigeye is 26 to 30% of fork length while in yellowfin and albacore it is 23 to 26% of fork length (Gibbs and Collette, 1967).

Another morphometric measurement is half girth. This curved measurement, which follows the body shape, has little identification value, as it is subject to seasonal change. In bluefin tuna, the half girth may vary from 30 to 40% of the fork length (Figure 7).

Another character that has been reported to be useful in tuna identification is the maximum diameter of the eye or iris. For specimens more than 65 cm long, the irises of albacore and bigeye are distinctly larger (>3 to 4% of head length) than those of bluefin or yellowfin (<3 to 4% of head length) (Figure 8). Mather (1962a) displayed this relationship for bluefin as two 'linear' lines (see Figure 8). The high variability of this truncated data set precludes identifying if the relationship is indeed two linear curves or some form of transformation. We have provided both an untransformed linear and power curve regression. Gibbs and Collette (1967) consider that only bigeye tuna over 60 cm can be separated from the other tunas with this character. The remainder have such overlap

Figure 8. Eye diameter and fork length of 215 bluefin tuna from the western Atlantic. These fish were sampled between 1963 and 19703 in the months June to October. The dotted line represents the relationship recorded by Mather (1962a). The linear equation represents the untransformed linear relationship of these data. The lower equation is the power curve (log) transformation.

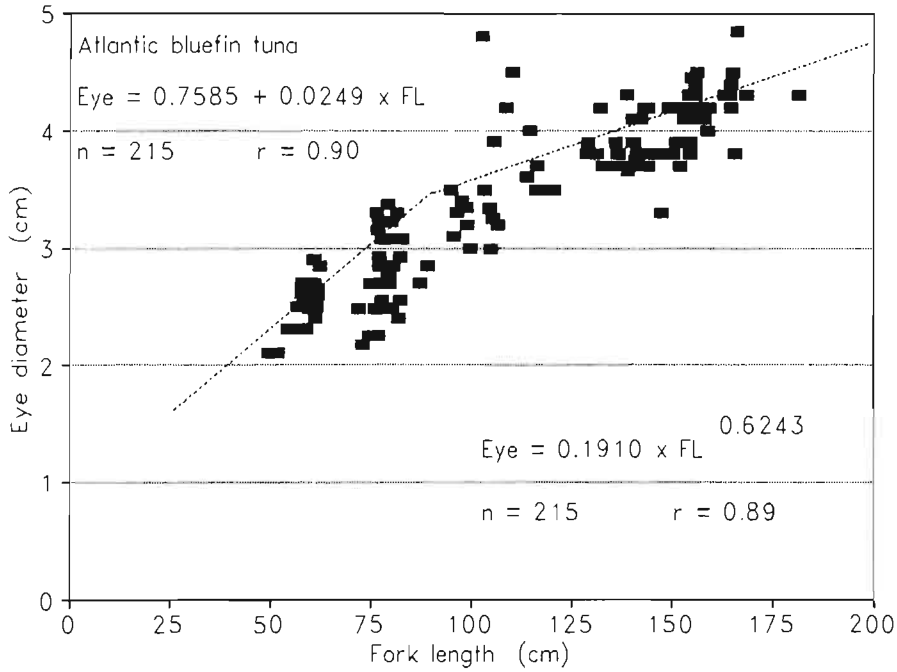
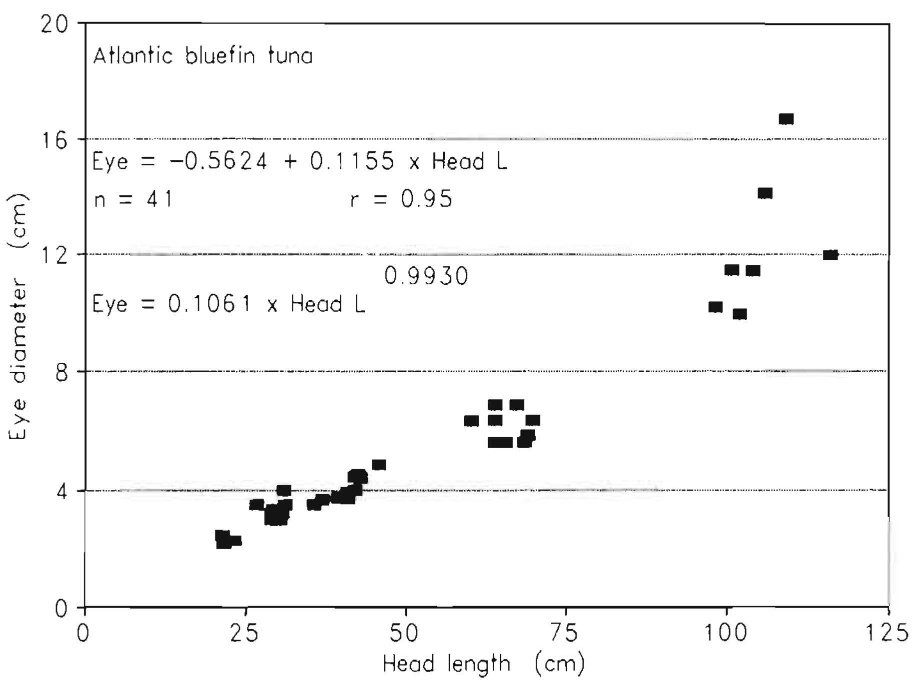


Figure 9. Eye diameter and head length of 41 bluefin tuna from the western Atlantic. These fish were sampled between 1963 and 1973 in the months June to October. The linear equation represents the untransformed linear relationship of these data. The equation in the lower right is the power curve (log) transformation.



that species distinction is not possible. The iris or eye diameter of small tuna cannot be used for such identification, (ie. some yellowfin less than 60 cm in length tend to be have relatively larger eyes than those of bluefin (Mather, 1962a)). The ratio of the eye diameter to head length (Figure 9) appears to have a different relationship from that of the eye diameter to fork length (Figure 8), possibly due to the allometric growth of the head.

b. Meristics: Counts of Different Body Parts

Fin ray counts have proved to be of little value in separating the tuna species, but the count of gill rakers on the first gill arch is very important (Table 2; Figure 3) (Gibbs and Collette, 1967). In most cases, counts of the total number of rakers on the first gill arch can be used to unambiguously separate bluefin (34-43) from the three other species of the genus Thunnus. The "low end" of the range for bluefin (counts of 34) does overlap with the "high end" of the range for yellowfin, but counts in this range are considered to be rare for bluefin.

Table 2. Meristic counts of tunas (Thunnus sp.) found in the northwest Atlantic (data from Mather, 1962a; Watson, 1962; Gibbs and Collette, 1967; Scott and Scott, 1988; and Miyake, 1990). The average number of gill rakers is indicated by brackets, the other two numbers for each character are the range.

Meristic character	bluefin	bigeye	yellowfin	albacore
dorsal spines	12-14	13-14	12-14	12-14
dorsal finlets	8-10	8-10	8-10	7- 9
pectoral rays	30-36	31-35	33-36	31-36
gill rakers	34-43(39)	23-31(27)	26-35(30)	23-31(28)
vertebrae	39	39	39	39

There is considerable overlap in the range of total gill raker counts for albacore, bigeye and yellowfin. Therefore, this character is of limited value for distinguishing between these three species of tuna. The total gill raker count permits unequivocal separation of skipjack (53-63) from all species of the genus Thunnus and the Atlantic little tunny. Although fin ray counts tend to be of little diagnostic value, counts of the total number of spines in the retractible, first dorsal fin may aid in separating tunas of the genus Thunnus (12-14) from the skipjack (genus Katsuwonus) (14-16) but not the Atlantic little tunny (genus Euthynnus) (11-14 rarely 15) (Table 2). The number of vertebrae can only be used to separate the genus Katsuwonus (42) from the genera Thunnus (39) and Euthynnus (39) (Watson, 1962).

c. Colour Patterns

Even though colouration may vary with origin or age among tunas of the same species, it can still be a useful character for identification purposes. Body colouration tends to fade rapidly after death but the fin and finlet colours usually remain longer. Crane (1936) observed the colour 'changed and faded entirely after ten minutes in the air'. The members of the genus Thunnus are iridescent dark blue dorsally and silvery white ventrally, without darker spots, longitudinal lines, or vermiculations (fine wavy markings) on their ventral, lateral and dorsal surfaces. They do however often exhibit white spots or streaks on young forms (Jim Beckett, personal communication, DFO, Ottawa). The finlets of most species are at least partly yellow, with the edgings usually a dusky colour.

Yellowfin are the most brilliantly coloured of the northwest Atlantic tuna, with a shining golden lateral band. Bigeye tuna may display a trace of a golden band, Crane (1936) noted a bluish bronze band that became brownish then apparently absent soon after death in bluefin tuna. In albacore tuna it is an iridescent blue band.

The dorsal finlets and often one or two of the largest anal finlets of albacore tuna have yellow centres, but generally the finlets are darker than those of the yellowfin, bigeye or bluefin tunas. The prominent white margin of the albacores caudal fin clearly separates it from all the other tunas of the genus Thunnus.

The finlets of bigeye tuna are yellow with broad, black edgings. Despite its name the bluefin has dusky yellow finlets with narrow, black edges. The median caudal keels of adult bluefin are black. The first dorsal fin is yellow or bluish and the second dorsal is reddish brown. The dorsal and anal fins and finlets of yellowfin tuna are bright yellow and the finlets have narrow black borders.

Skipjack tuna have 3-5 (rarely 6) conspicuous longitudinal dark bands or stripes on both sides of their abdomen. The little tunny has blue-green striped markings between the bases of the two dorsal fins and several black spots between the pectoral and pelvic fins.

Tuna Identification Based on Internal Characters

The identification of tuna using internal characters often requires a great deal of preparation (ie. extensive dissections and/or x-rays) and professional taxonomic experience. The only exceptions to this are a few easily identifiable characteristics of the liver (Watson, 1962), flesh colouration and a little studied and, in Atlantic Canada, seldom used characteristic of the anterior dorsal wall of the body cavity (Godsil and Holmberg, 1950).

a. Liver

The characteristics of tuna livers that contribute to species identification are:

i. presence or absence of striations (blood vessels) on the ventral (bottom) surface of the liver, and
ii. variability in the lengths of the three lobes.

The livers of bluefin, bigeye and albacore tuna (Appendix III; Appendix IV) have striations on the ventral surfaces and three equal sized lobes (or the middle lobe may be slightly longer). In contrast, the liver of a yellowfin tuna has smooth, unstriated ventral surfaces, and a long right lobe (when viewed ventrally).

b. Flesh

The distribution patterns of red and white muscle in the body of tunas show characteristic variations by species and may be used as an additional aid to species identification, especially in the case of damaged specimens (Figure 10). However, identification using these characteristics could be compromised when there are differences in the sizes of the specimens to be identified or if one or more of the specimens exhibits "yake" (turbid or 'burnt' (cooked) flesh resulting from excessive stress during capture or poor handling).

c. Body cavity 'pockets'

Many Japanese fishermen have described the use of a "fist" measurement of pockets in the interior of the body cavity of dressed tuna to determine the species. This characteristic has since been investigated by DFO staff and found to warrant further study.

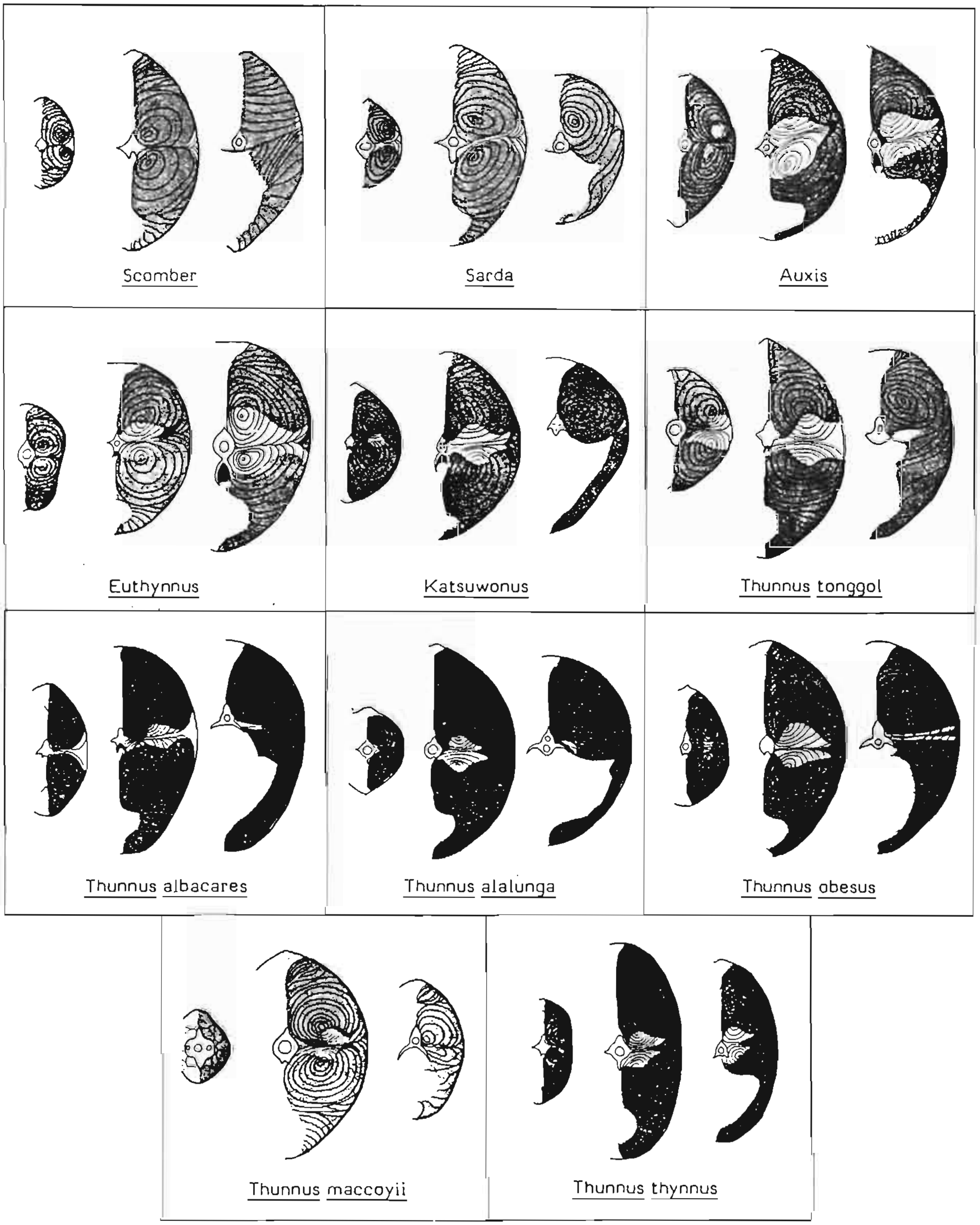
Godsil and Holmberg (1950) and Gibbs and Collette (1967) described the presence of a wide, anterior bulge in the dorsal wall of the body cavity of bluefin tuna with distinctive deep, narrow troughs lateral to the bulge (referred to as "lateral trough pockets"). These pockets are well formed in bluefin larger than 130 cm fork length.

This characteristic was initially considered as a distinction between the tuna species of the "bluefin tuna complex" (Thunnus maccoyii (Castelnau, 1872) - the southern bluefin and the two subspecies of Thunnus thynnus: Atlantic bluefin tuna Thunnus thynnus thynnus from the north Atlantic Ocean and the northern bluefin tuna Thunnus thynnus orientalis from the north Pacific Ocean). Recent evidence indicates that this characteristic may also be used for distinguishing Atlantic bluefin from the other species of tuna caught within the Canadian EEZ.

A cursory evaluation of this characteristic at the 'Tuna Identification Workshop' given by the authors in Yarmouth, Nova Scotia (NS) in June 1990, confirmed the value of this characteristic. Sixteen specimens representing five of the six species known to occur in Canadian waters were examined and only bluefin were found to have these pockets. A DFO Conservation and Protection Officer who has examined more than a thousand tuna in the whole and round condition (predominately bluefin) also attested to the validity of this characteristic (Bryce Duggan, personal communication, DFO, Barrington Passage, NS).

Although this suggests these 'pockets' are not found in the other species caught within the Canadian EEZ, a directed study is required for confirmation. If validated, this characteristic will represent an extremely powerful diagnostic tool for the identification of bluefin tuna, especially in the dressed form.

Figure 10. Distribution of red (white areas) and white (black and grey areas) muscle in eleven scombrid species. The three illustrations for each species correspond (l to r) with the anterior end of the caudal keels, midpoint of body, and posterior edge of gill cover (from Collette and Nauen, 1983).



Tuna Identification Based on Chemical Analysis

Although not a 'real' time technique for tuna identification, various laboratory chemical analysis techniques have been used to identify bluefin tuna. Early work by Edmunds and Sammons (1971, 1973) used electrophoresis to confirm the similarity of bluefin tuna from the east and west Atlantic. Phipps (1980) used a similar technique to try to separate two 'groups' of bluefin entering St. Margarets Bay, NS. One of the first published attempts to use the electrophoretic technique described in Sharp and Pirages (1978) to positively identify an unknown fish (subsequently identified as a northern (Pacific) bluefin (T. thynnus orientalis)) was conducted by Dotson and Graves (1984).

A new more sensitive technique referred to as DNA sequence analysis has become an accepted tool for species and even individual identification (Fourney et al., 1989). The enforcement and subsequent management difficulties experienced by DFO in 1988 and 1989 prompted research support to be provided to both the RCMP forensic lab in Ottawa and the Biochemistry Department at Memorial University of Newfoundland. These two labs used molecular DNA techniques to indentify genetic markers to positively identify bluefin tuna from the other tuna species found in the Canadian EEZ (Bartlett and Davidson, 1991).

III. SIZE CONVERSIONS

Introduction

Declining catch rates in the Canadian inshore bluefin fishery prompted the DFO in 1987 to encourage efforts to develop offshore tuna longline fisheries directed to unregulated species such as bigeye and yellowfin tuna. Domestic allocations of the internationally agreed Canadian quota for bluefin tuna were held at 35 tonnes per vessel to force the fishermen involved to fish for other species. Coincident with this was the sudden appearance of interest and effort in 1988 towards two mid-shore local concentrations of bluefin tuna. These two areas of bluefin occurrence were previously known (Jim Beckett, personal communication, DFO, Ottawa), however, the distance from shore and previous low value of bluefin resulted in little interest. The small vessels of the inshore fleet have moved quickly in the past two years to exploit this resource.

The major Canadian bluefin fisheries have traditionally been inshore, using fixed traps, harpoon (until 1972), rod and reel and since 1981 'tended line'. From 1988 to 1990 the majority of the traditional catch has been taken in the two new 'mid-shore' areas:- the Virgin Rocks on the Grand Banks of Newfoundland and a small area known as the 'Hell Hole', in the Northeast Channel, between Browns Bank and Georges Bank (Figure 11).

The development of these mid-shore bluefin tuna fisheries southeast of Nova Scotia and east of Newfoundland, since 1988, has resulted in new sampling difficulties. These fisheries occur far from shore (approximately 185 km) and require at-sea butchering and icing to maintain a high quality. The vessels taking part in these fisheries are, of necessity, larger in size (13 to 18 m) than the average in the traditional inshore fishery. The fish are shot as they are brought alongside, hoisted onto a table on deck, butchered and placed in ice-filled containers for the return trip to port.

As a result of these processing measures, a high value, high quality fresh tuna product can be delivered to the Japanese market within four days of capture. It is difficult for biologists to obtain biological sampling data. Conversion factors are required to convert the landed dressed fish to round or live weight equivalents for quota monitoring. In recent years the DFO has used an old conversion factor of 1.3 from an unknown source to convert dressed weight to round weight. Many industry representatives and biologists have warned that this conversion factor may not be representative of the fishery. Consequently, we have analysed the available data to provide the most representative conversion factors available at this time.

Previous Studies

Recent reviews of length weight relationships for bluefin tuna by Parrack (MS 1990) and Cort and Liorzou (MS 1990) indicate that this subject has received little attention since the 1970's. Rodriquez-Roda (1971) summarized bluefin length weight data for pre- and post-spawning eastern Atlantic bluefin. Baglin and Farber (1980) indicated that many of the earlier studies had access to (or presented only) incomplete data sets, which resulted in many questions being left unanswered.

Figure 11. Catch by longline set of Atlantic bluefin tuna from the Canadian offshore longline fishery between 1987 and 1989. The size of each set, expressed in kg, is represented by expanding circles. Data are from the IOPs (International Observer Program) in Halifax and St. Johns.

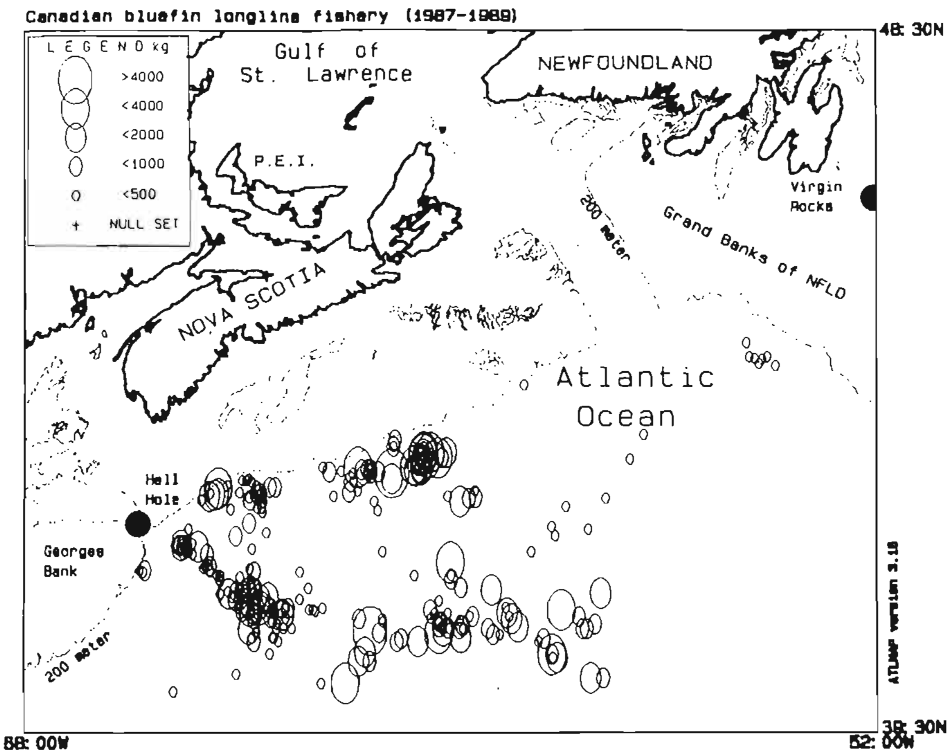
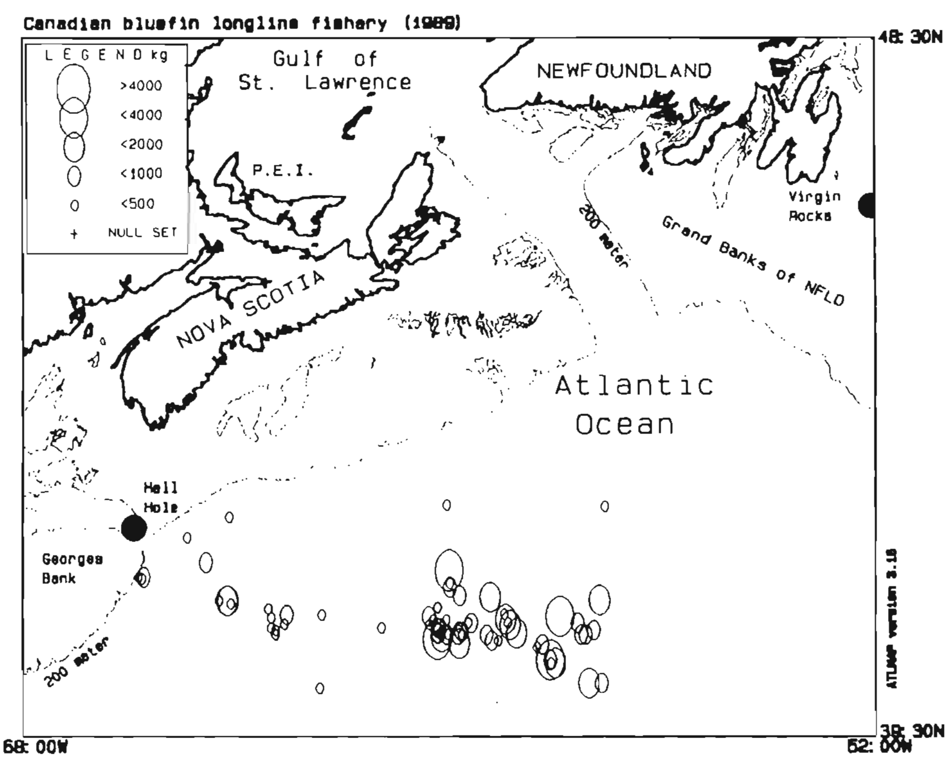


Figure 12. Catch by longline set of Atlantic bluefin tuna from the Canadian offshore longline fishery in 1989. The size of each set, expressed in kg, is represented by expanding circles. Data are from the IOPs in Halifax and St. Johns.



Staff of the St. Andrews Biological Station, then a part of the Fisheries Research Board of Canada, provided bluefin tuna data to Mather et al. (1974) for the conversion factor from round weight to length that was used in early stock assessment work for Canadian and New England (USA) fisheries. A dressed weight (DW - kg) to round weight (RW - kg) conversion

$$(DW = 2.02 + 1.2593\ RW)$$

was also provided for bluefin.

Parrack (1980) presented seasonal fork length to round weight (and vice versa) conversions as well as a dressed weight to round weight conversion factor of 1.25. These seasonal length weight conversions are used by ICCAT for conversion of west Atlantic bluefin, in particular for the Canadian inshore catch which is generally 100% sampled, although for weight only.

Methods

Least squares linear regression (Snedecor and Cochran, 1978) was used to develop various size relations for this Atlantic tuna data. Visual editing of initial plots was done to remove obvious outliers (about 0.5% of the observations). Two data sets were available for these analyses. The first is the shore based, commercial sampling data for bluefin tuna from along the Atlantic coast of Canada, collected between 1974 and 1985. This data set is comprised mostly of fish from the Prince Edward Island (PEI) inshore fishery in the Gulf of St. Lawrence. The variables analysed from this data set were: fork length - the straight line measurement from the tip of the upper jaw to the fork in the tail measured with calipers; round weight - the weight of the whole (live) fish, which may be biased by blood loss due to quality control measures; dressed weight - the carcass weight after the fish is gutted, beheaded, and de-tailed; dressed length - the straight line measurement of the butchered carcass from the caudal 'stump' to the inside of the cleithral arch. All weights were measured in pounds and converted to the nearest whole kg, and all lengths were measured to the nearest cm. An earlier collection of data (1963 to 1973) were also available for analysis. Although it is known that these data are from Canadian coastal fisheries, exact locations are uncertain. For this reason these data were used only for confirmation of the other data sets.

The second data set for this study was collected at sea by the International Observer Program (IOP) of the DFO, Canada. This program has two independent components in the Atlantic zone, one based in St. John's, Newfoundland (Newfoundland Region: NFLD) and one in Halifax, NS (Scotia Fundy Region: SF). Each component serves vessels based in the adjacent areas and maintains its own data sets.

The latter data set was collected on Canadian, Canadian chartered and Japanese longline vessels fishing for tuna and tuna like species within the Canadian EEZ in the northwest Atlantic. Data on all species caught for the years 1987 to 1989 were available. All data in this set, except the 1989 Newfoundland observer program, were collected in 1 cm and 1 kg intervals for length and weight measurements respectively. The 1989 Newfoundland data were collected in 5 cm intervals for all length measurements. The same data variables were examined in this analysis.

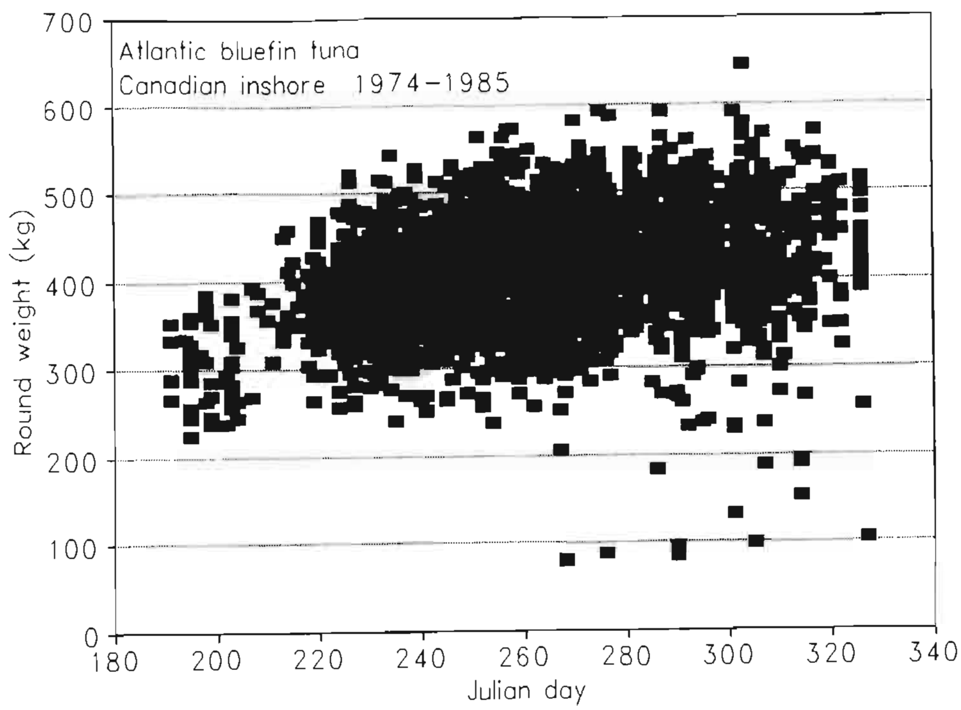
Results and Discussion

The offshore Atlantic tuna longline fisheries generally occur along the 'shelf break', approximately over the 1,000 m depth contour. During 1989 (Figure 12) the fishery shifted farther offshore.

Of the two 'traditional' mid-shore areas, the Hell Hole is close to some of the offshore longlining fishing grounds while the Virgin Rocks is a great distance away. We assume that bluefin caught in the 'mid-shore' and offshore fisheries are from related stock components. Complete catch and sampling data are available from the offshore fisheries, however, the same is not the case for the mid-shore and inshore fisheries and thus conversion factors are required. Because recent biological data are not available for the adjacent traditional fisheries, these conversion factors were derived from biological sampling data collected from the offshore longline fishery (Figure 11).

An analysis of covariance (Snedecor and Cochran, 1978) conducted on the monthly offshore longline data set indicates no significant difference ($p > 0.05$) between the fork length and round weight relationships of males and females. Homogeneity of the variances was found in this analysis. For all other analyses the sexes were combined. Sexual dimorphism in the relationships may not have occurred because these fish were sampled from the northern limit of the feeding migration at a time when they are in a sexually 'resting' stage (ie. not ripe).

Figure 13. Round weight (kg) of individual bluefin port sampled from the inshore Canadian fisheries 1974 to 1985. Julian day is the sequential date from January 1 of the year of sampling.



The inshore port sampling data combined for the years 1974 to 1985 do not indicate a significant increase in the mean weight of fish as the fishing season progresses, however, analysing the data year by year the within fishing season regressions are significant (Figure 13). There is also an increase in the mean weight of fish over the twelve year period of available data (Figure 14). As these data are combined from several fisheries, individual trends tend to mask one another, however when individual fisheries (ie. PEI in the southern Gulf of St. Lawrence) are investigated very definite increasing trends can be observed. This increase in annual mean weight is not the cause of the increasing seasonal weight. The data indicate a seasonal increase in weight at length over the range of lengths analysed (Figure 15). Comparing the weight at length for pairs of consecutive months (ie. July and August) the increase in weight ranges from over 15% for a 200 cm tuna between July and August to a slight decline in weight between October and November (Figure 16). For the largest size group (285 to 305 cm) the increase in weight is about 7.5% per month throughout the season. Length and weight data from the period 1963 to 1973 included samples of smaller fish that were more common at that time (Figure 17).

The monthly length weight relationships for inshore giant bluefin in the northwest Atlantic are listed in Table 3. Both the arithmetic mean (AM) and geometric mean (GM) regressions are provided (Ricker, 1975). The relatively poor coefficients of determination (r^2) compared to those obtained from the offshore longline data (eg. Table 4) are due to the limited range of size of the tuna in the traditional inshore fisheries. The month/year combinations with the highest coefficents of determination generally had a small number of fish in the 100 to 200 cm length range.

The fork length to round weight relationship (Table 4 and Figure 18) for the offshore longline data for the months November to February represents fish near the end of their feeding migration in northern temperate waters. These fish should be in near optimal condition with respect to fat reserves, in preparation for early spring spawning in the Gulf of Mexico.

Figure 14. Round weight (kg) of individual bluefin port sampled from the inshore Canadian fisheries 1974 to 1985 by year. Julian day is the sequential date from January 1 1974. Numbers below the columns indicate the year of sampling. The solid line represents the mean weight of bluefin from the southern Gulf of St. Lawrence (PEI).

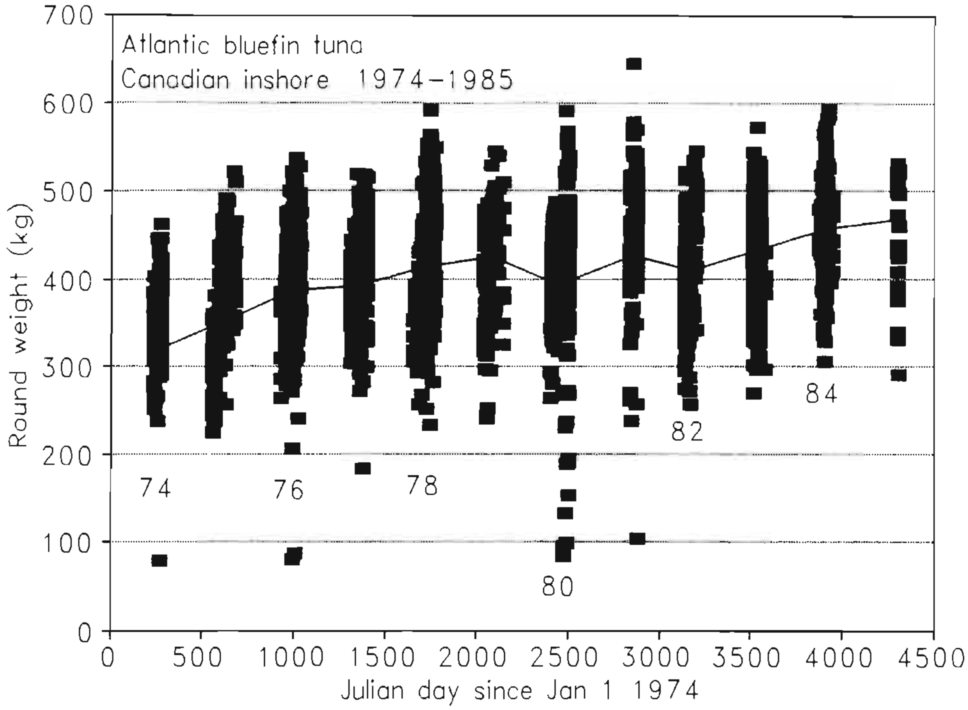


Figure 15. Length weight relationships of Atlantic bluefin tuna port sampled from the inshore Canadian fisheries 1974 to 1985. The relationships are by month for the size range representing the majority of the sampled fish.

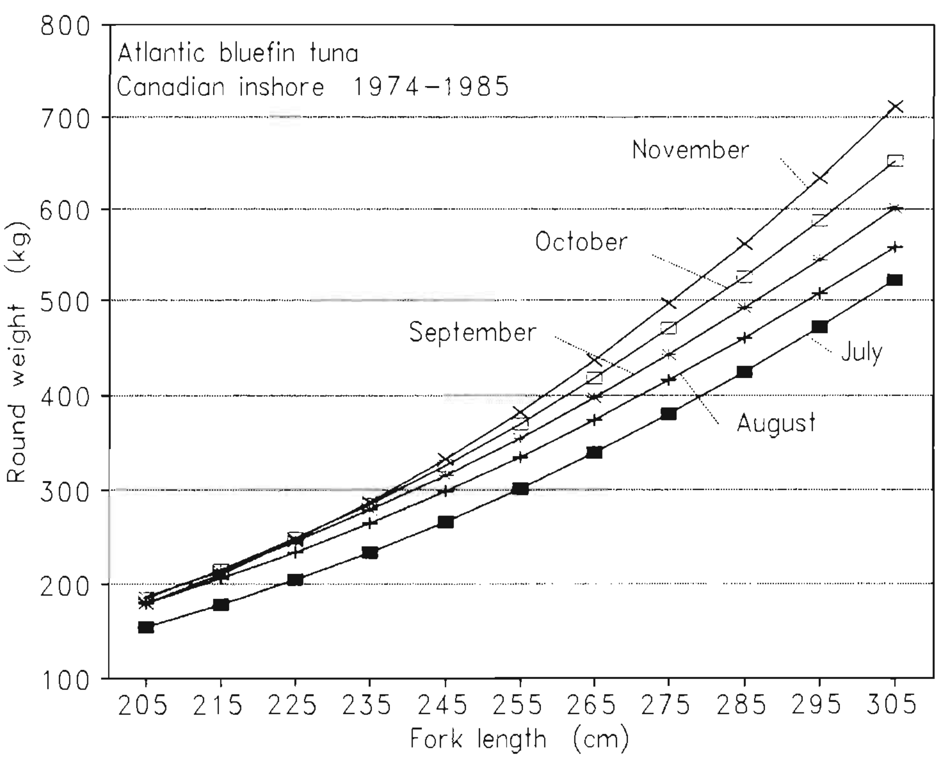


Table 3. Fork length to round weight relationship of Atlantic bluefin tuna (Thunnus thynnus, L.) collected by the Department of Fisheries and Oceans, Canada port sampling programs 1974 to 1985. 'Type' refers to arithmetic mean (AM) and geometric mean (GM) (Ricker, 1975) regression.

Month	Sample years	Size range	n	r^2	Type	a	b
July	1974 - 1977	235 - 280 cm	47	0.85	AM	0.00000562	3.2135
		235 - 390 kg			GM	0.00000127	3.4820
July	1978 - 1980	265 - 285 cm	10	0.34	AM	0.02502114	1.7037
		305 - 400 kg			GM	0.00002367	2.9453
July	1974 - 1980	235 - 285 cm	57	0.83	AM	0.00005293	2.8071
		235 - 400 kg			GM	0.00001157	3.0813
August	1974 - 1977	235 - 295 cm	310	0.54	AM	0.00355970	2.0727
		260 - 485 kg			GM	0.00005619	2.8160
August	1978 - 1980	220 - 300 cm	164	0.59	AM	0.00520085	2.0021
		245 - 500 kg			GM	0.00016606	2.6179
August	1981 - 1985	240 - 300 cm	298	0.65	AM	0.00020526	2.5865
		270 - 545 kg			GM	0.00000589	3.2199
August	1974 - 1985	220 - 300 cm	772	0.59	AM	0.00178792	2.1971
		245 - 545 kg			GM	0.00004357	2.8612
September	1974 - 1977	155 - 300 cm	598	0.72	AM	0.00029750	2.5259
		85 - 520 kg			GM	0.00002433	2.9753
September	1978 - 1980	235 - 300 cm	218	0.54	AM	0.00208782	2.1865
		260 - 560 kg			GM	0.00002454	2.9831
September	1981 - 1985	230 - 300 cm	364	0.65	AM	0.00078531	2.3549
		260 - 580 kg			GM	0.00001531	3.0562
September	1974 - 1985	155 - 300 cm	1180	0.67	AM	0.00058695	2.4066
		85 - 580 kg			GM	0.00002916	2.9441
October	1974 - 1977	150 - 290 cm	282	0.78	AM	0.00038174	2.4893
		85 - 545 kg			GM	0.00005970	2.8222
October	1978 - 1980	165 - 300 cm	369	0.87	AM	0.00001434	3.0800
		85 - 595 kg			GM	0.00000422	3.2991
October	1981 - 1985	220 - 305 cm	141	0.73	AM	0.00029124	2.5470
		245 - 645 kg			GM	0.00002628	2.9776
October	1974 - 1985	150 - 305 cm	792	0.83	AM	0.00004062	2.8939
		85 - 645 kg			GM	0.00000859	3.1722
November	1974 - 1977	240 - 285 cm	41	0.75	AM	0.00009281	2.7524
		305 - 520 kg			GM	0.00000850	3.1825
November	1978 - 1980	195 - 295 cm	118	0.86	AM	0.00001170	3.1202
		160 - 570 kg			GM	0.00000294	3.3685
November	1981 - 1985	185 - 290 cm	48	0.96	AM	0.00000726	3.2189
		115 - 570 kg			GM	0.00000495	3.2877
November	1974 - 1985	185 - 295 cm	206	0.84	AM	0.00000884	3.1745
		115 - 570 kg			GM	0.00000167	3.4736

Table 4. Length and weight relationships from Atlantic bluefin tuna (Thunnus thynnus, L.) collected by the Scotia Fundy IOP during 1989 on longline vessels in the northwest Atlantic. These samples were collected in January, February, November and December (n=278, 158, 218, and 1047 fish respectively). The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) {68-290 cm} : round weight (RW) {8-400 kg}

$$RW\ (kg) = 0.20883 \times 10^{-4} \times FL\ (cm)^{2.97770};\ n=1737;\ r^2=0.96$$

$$FL\ (cm) = 39.37181 \times RW\ (kg)^{0.32369};\ n=1737;\ r^2=0.96$$

Fork length (FL) {79-290 cm} : dressed weight (DW) {9-365 kg}

$$DW\ (kg) = 0.11073 \times 10^{-4} \times FL\ (cm)^{3.06871};\ n=1737;\ r^2=0.96$$

$$FL\ (cm) = 43.34364 \times DW\ (kg)^{0.31407};\ n=1737;\ r^2=0.96$$

Fork length (FL) {78-290 cm} : dressed length (DL) {68-258 cm}

$$DL\ (cm) = -6.38767 + 0.87441 \times FL\ (cm);\ n=1212;\ r^2=0.96$$

$$FL\ (cm) = 14.08823 + 1.09945 \times DL\ (cm);\ n=1212;\ r^2=0.96$$

Dressed length (DL) {68-258 cm} : round weight (RW) {12-400 kg}

$$RW\ (kg) = 0.12754 \times 10^{-4} \times DL\ (cm)^{2.72523};\ n=1174;\ r^2=0.93$$

$$DL\ (cm) = 30.53428 \times RW\ (kg)^{0.33951};\ n=1174;\ r^2=0.93$$

Dressed length (DL) {68-258 cm} : dressed weight (DW) {9-365 kg}

$$DW\ (kg) = 0.72704 \times 10^{-4} \times DL\ (cm)^{2.80495};\ n=1178;\ r^2=0.92$$

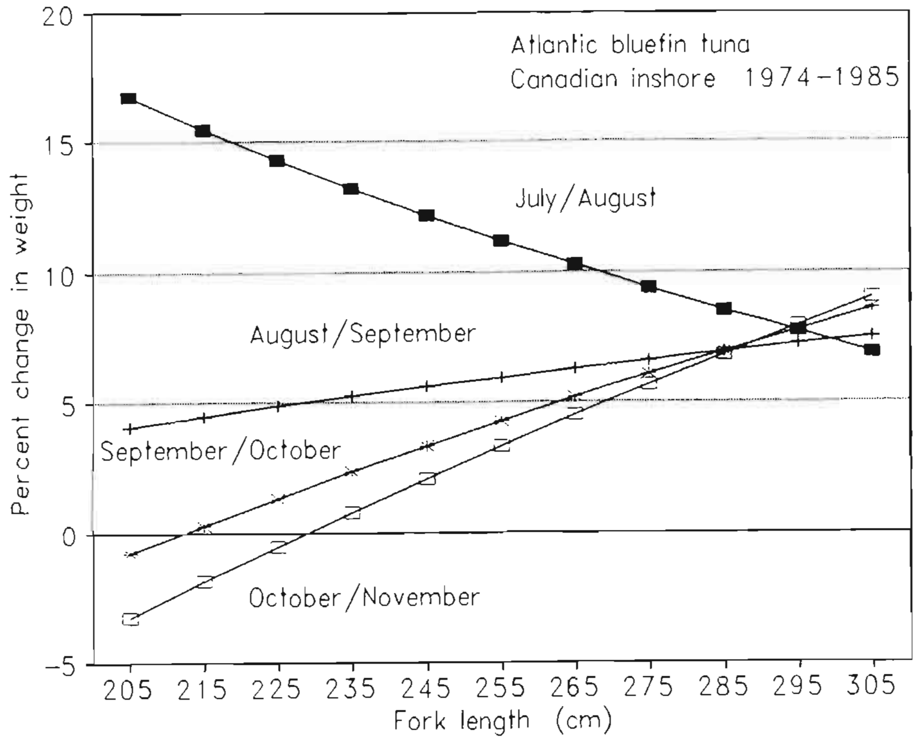
$$DL\ (cm) = 33.72940 \times DW\ (kg)^{0.32978};\ n=1178;\ r^2=0.92$$

Dressed weight (DW) {9-361 kg} : round weight (RW) {12-400 kg}

$$RW\ (kg) = 2.15948 + 1.14812 \times DW\ (kg);\ n=1707;\ r^2=0.99$$

$$DW\ (kg) = -1.56672 + 0.86804 \times RW\ (kg);\ n=1707;\ r^2=0.99$$

Figure 16. Percentage change in weight between bluefin tuna of the same length measured in consecutive months. These fish are port sampled from Canadian fisheries 1974 to 1985.

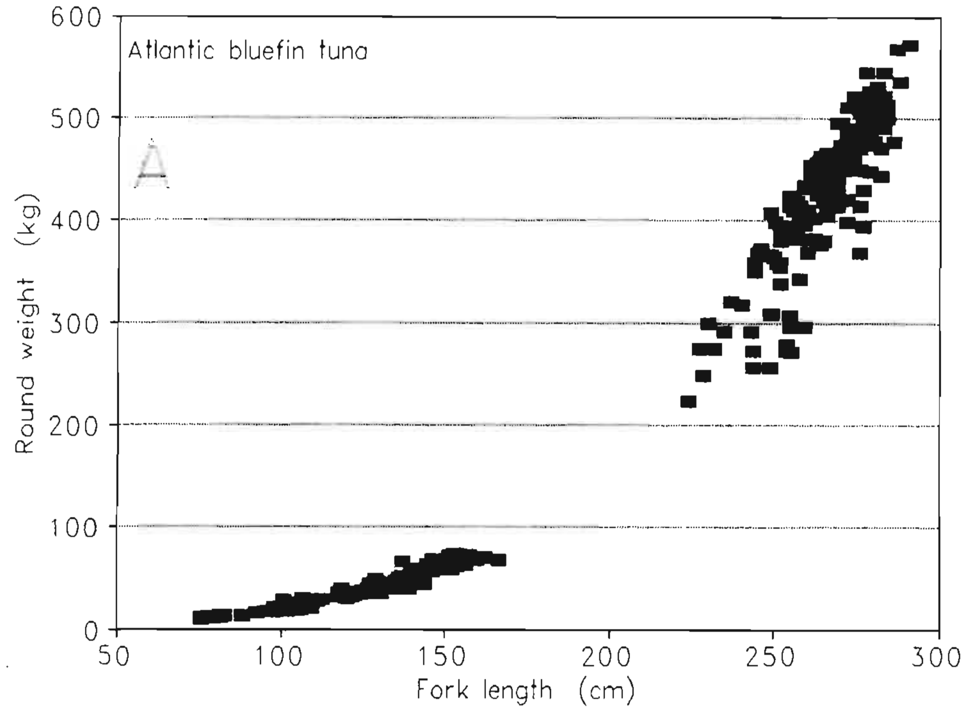


An analysis of covariance of the IOP data by month (November through February) indicates a significant difference ($p < 0.01$) between pairs of consecutive months (Figure 19). The difference in the weight at length (150 cm) of a sampled fish was approximately 10% in the extreme case. Such a decline in weight between fish at the beginning (November) and end (February) of the (fishing) year is probably caused by earlier movement of 'fatter', larger fish from the feeding grounds towards the southern spawning grounds. It is also possible, although the authors consider improbable, that the remaining fish feed less and thus actually loose condition (weight). The cyclical pattern (Figure 19) indicates this apparent decline in weight is due to the seasonal migration.

We have decided to combine our dataset to provide an 'average' estimate for these late season conversion factors (Table 4). The monthly length weight relationships and weights at a common length of the sampled fish are provided in Table 5.

Although we assume less error in the measurement of length compared to the measurement of weight, for the purpose of providing conversion factors in both 'directions' for each relationship we have assumed perfect data for both size measures. The most important relationships for our work are the conversion of dressed weight to fork length (Table 4, Figure 20) and dressed weight to round weight (Table 4, Figure 21). A similar relationship was observed from the 1963 to 1973 inshore data (Figure 22). These data have about a 6% difference between them. There are two explainations, the true difference probably being a combination of the two. The first is a possible difference in dressing technique, the recent more highly valued tuna being more 'carefully' dressed to produce 6% more product. The second difference between these data sets was the time of year of sampling. The inshore data were generally collected July through September while the IOP data were mostly collected December through February, a time of higher fat content and thus a higher body to head and visera ratio. Day (1952) produced summarized data that indicated a curvilinear relationship for fish smaller than 150 cm (50 kg round weight), his data for fish over 150 cm is approximately equal that presented here (Table 6). Baglin and Faber (1980) presented conversion factors for summer caught giants along the US east coast that ranged from 1.25 to 1.30.

Figure 17. Length weight relationship of Atlantic bluefin tuna from inshore sampling collected between 1963 and 1973 in the months June to October. Figure B is the same data as Figure A, for small fish only.



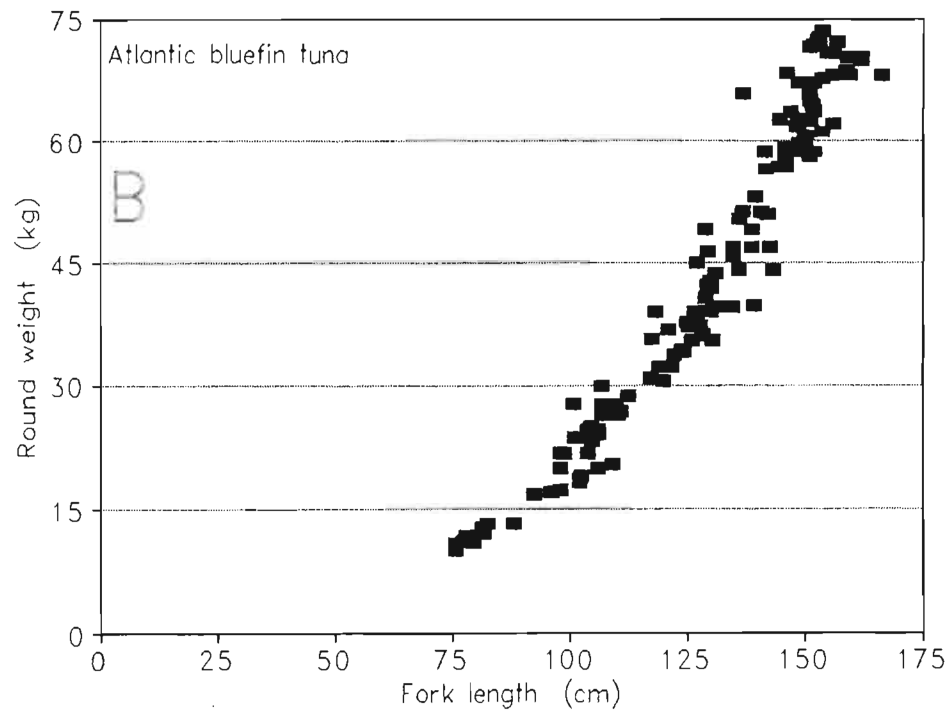


Table 5. Monthly length and weight relationships from Atlantic bluefin tuna (Thunnus thynnus, L.) collected by the IOP during 1988 and 1989 on longline vessels within the Canadian EEZ. Predicted weight for a 200 cm bluefin is given for each regression equation. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) {79-247 cm} / round weight (RW) {10-221 kg}

January: mean weight of 200 cm bluefin 117.5 kg
(FL) {79-247 cm} (RW) {10-221 kg}

$RW\ (kg) = 0.23699 \times 10^{-3} \times FL\ (cm)^{2.47514}$; $n = 870$; $r^2 = 0.85$

February: mean weight of 200 cm bluefin 129.1 kg
(FL) {69-225 cm} (RW) {6-168 kg}

$RW\ (kg) = 0.44923 \times 10^{-4} \times FL\ (cm)^{2.80694}$; $n = 713$; $r^2 = 0.96$

October: mean weight of 200 cm bluefin 144.7 kg
(FL) {66-256 cm} (RW) {5-300 kg}

$RW\ (kg) = 0.28274 \times 10^{-4} \times FL\ (cm)^{2.91575}$; $n = 30$; $r^2 = 0.99$

November: mean weight of 200 cm bluefin 147.1 kg
(FL) {60-273 cm} (RW) {4-412 kg}

$RW\ (kg) = 0.19711 \times 10^{-3} \times FL\ (cm)^{2.55231}$; $n = 1672$; $r^2 = 0.85$

December: mean weight of 200 cm bluefin 147.1 kg
(FL) {52-290 cm} (RW) {6-400 kg}

$RW\ (kg) = 0.64271 \times 10^{-4} \times FL\ (cm)^{2.76379}$; $n = 1648$; $r^2 = 0.86$

Annual combined estimate:
(FL) {52-290 cm} (RW) {4-412 kg}

$RW\ (kg) = 0.49535 \times 10^{-4} \times FL\ (cm)^{2.80874}$; $n = 4932$; $r^2 = 0.90$

Figure 18. Fork length (cm) to round weight (kg) relationship for bluefin tuna from the 1989 offshore longline fishery.

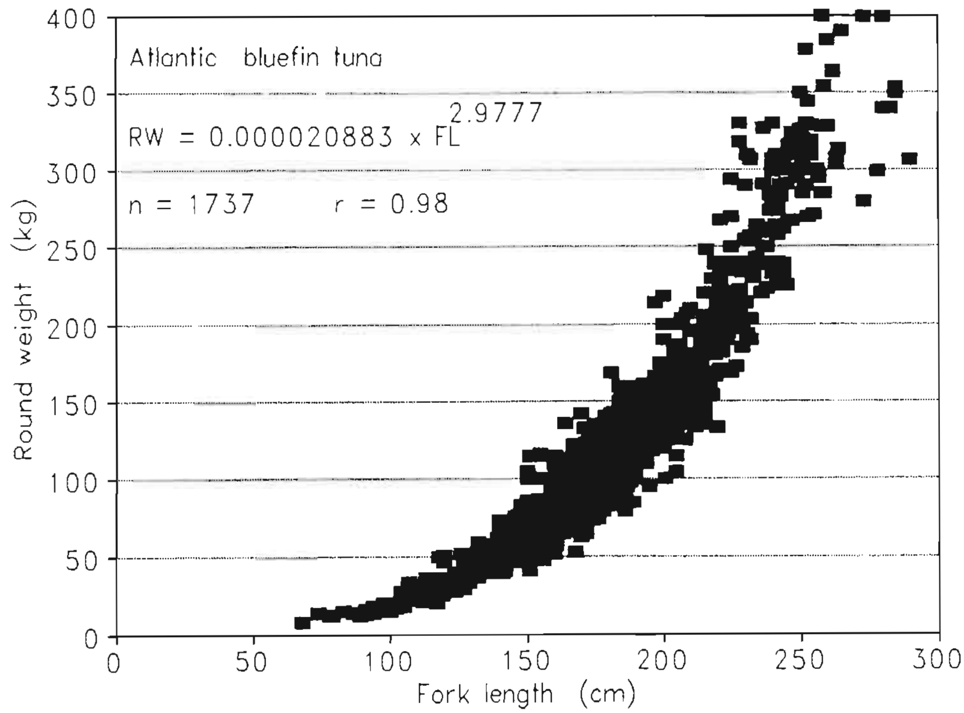


Table 6. Dressed weight to round weight conversion for bluefin tuna caught during summer and fall between 1949 and 1951 from St. Margarets Bay, NS (after Day, 1952).

FLANK LENGTH	N	DRESSED WEIGHT	ROUND WEIGHT	CONVERSION FACTOR
<114 cm	8	16 kg	20 kg	x 1.26
114-127	8	21	33	x 1.26
127-139	6	32	41	x 1.27
139-152	12	43	52	x 1.22
152-165	13	54	65	x 1.21
--				
241-266	2	229	278	x 1.21

The data indicate that the conversion for dressed weight to round weight of 'fat' (winter/offshore) fish is approximately 1.15. The conversion for the thinner fish caught earlier in the year (July and August) by the inshore traditional fishery is higher; in this case nearly 1.22. The Northwest Atlantic Fisheries Organization (NAFO) based in Dartmouth, NS has collated a wide variety of weight (processed) conversion factors (Table 7) that can be considered approximations for Canadian bluefin until local data become available (Anon, 1980).

Additional conversions between lengths and weights of bluefin tuna are provided in Table 4. Many records collected by fishermen and others have been expressed in terms of 'curved' (tape measure) flank length. A conversion ranging from 0.97 at 100 cm fork length to 0.93 at 300 cm (Figure 23) can be used on summer/fall 'inshore fish' to change these measures to 'straight' upper jaw fork length. Parrack (1980) derived a conversion factor of 0.95 while Day (1952) for a limited

Figure 19. Length weight relationships of bluefin tuna collected from the Canadian offshore longline fishery in November and December of 1988 and January and February of 1989. The cross hairs indicate the mean length and weight for those bluefin sampled.

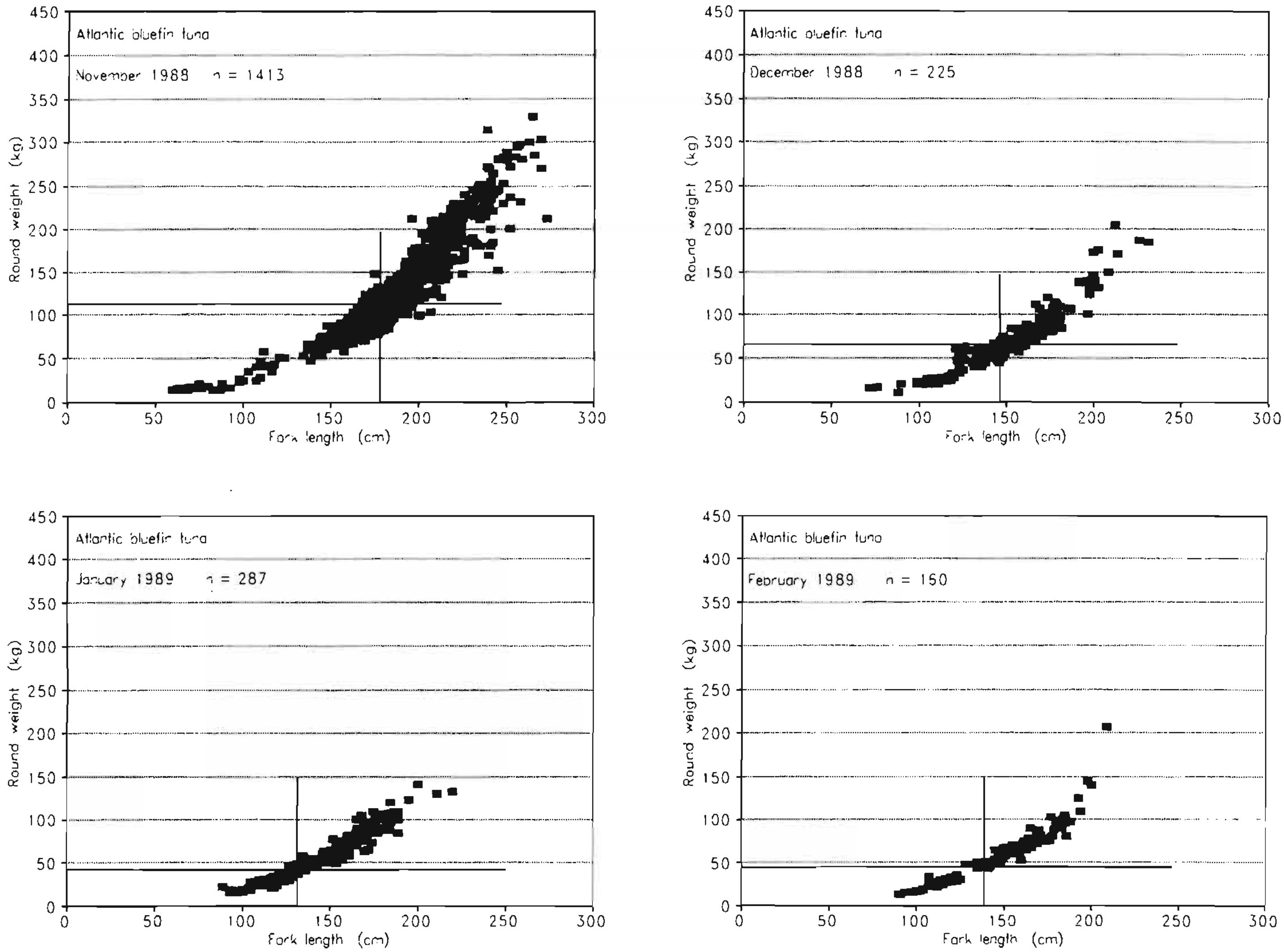


Figure 20. Dressed weight (kg) to fork length (cm) relationship for bluefin tuna from the 1989 offshore longline fishery.

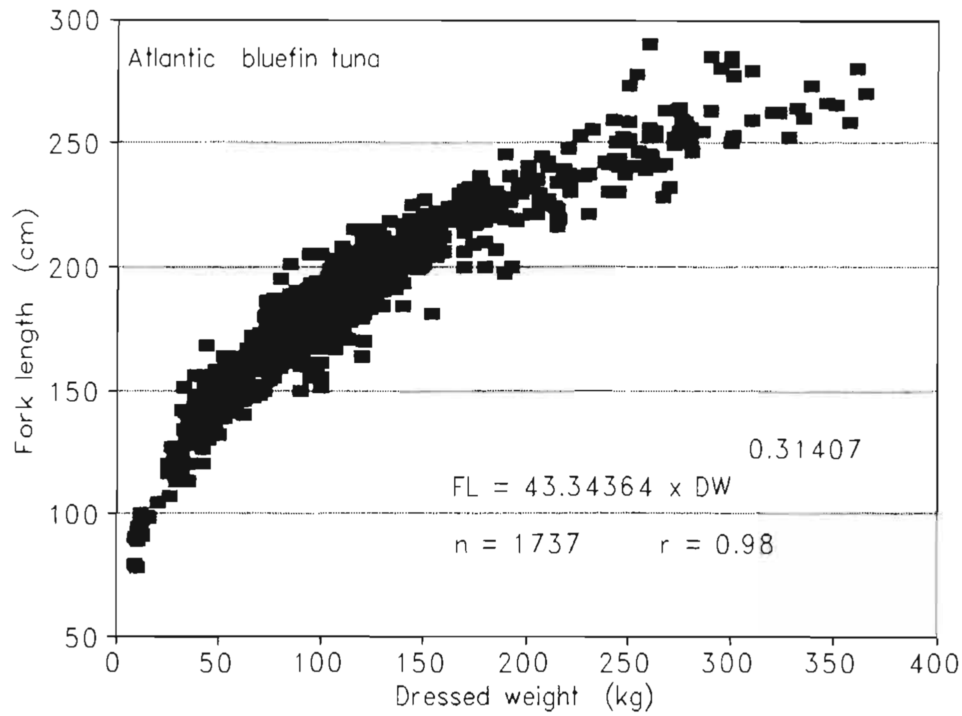


Figure 21. Dressed weight (kg) to round weight (kg) relationship for bluefin tuna from the 1989 offshore longline fishery.

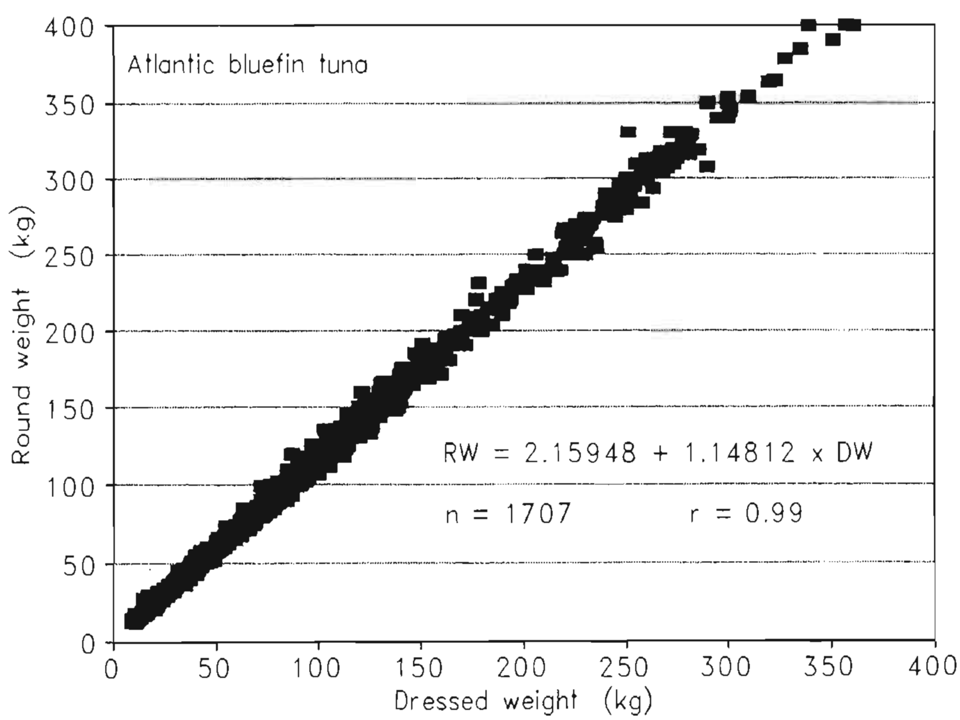


Figure 22. Dressed weight to round weight relationship of Atlantic bluefin tuna sampled from the inshore Canadian fisheries between 1963 to 1973 in the months of June to October.

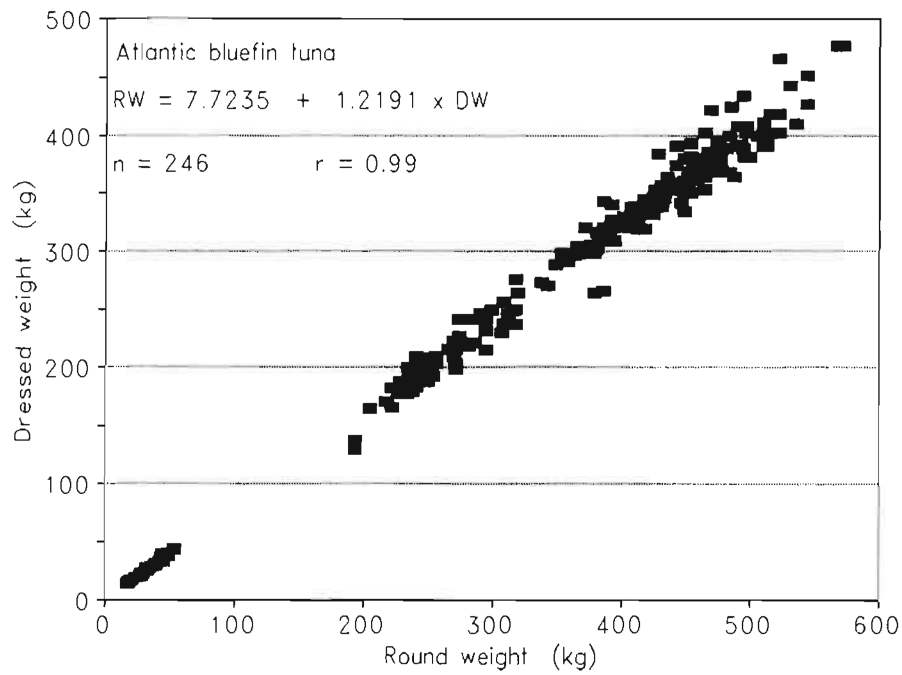
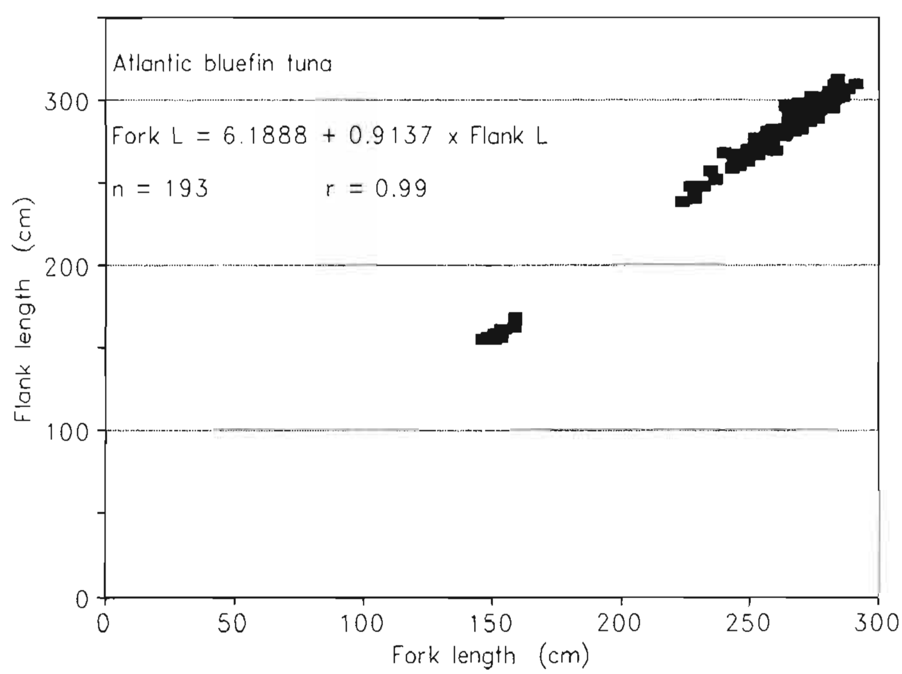


Figure 23. Fork length to flank length relationship of Atlantic bluefin tuna collected from inshore port sampling between 1963 and 1973 in the months June to October.



sample of small fish (110 to 150 cm fork length) from St. Margarets Bay, NS estimated 0.96. Seasonal length to weight conversions of other species commonly encountered in the offshore longline fisheries are provided in Appendix V (bigeye tuna: Table V.1; yellowfin tuna: Table V.2; albacore tuna: Table V.3; and swordfish (Xiphias gladius): Table V.4).

Table 7. Weight conversions for various processing techniques on east Atlantic bluefin tuna. (after Anon, 1980.)

PROCESS	COUNTRY	CONVERSION FACTOR
Gutted, head on, tail on Fresh, chilled, iced	Germany	1.20
Gutted, head off, tail on Fresh, chilled, iced	France Denmark	1.11 1.30
Gutted, head off, tail on Frozen	Germany	1.50
Fillets, skinless Frozen	Germany	4.00

IV. SUMMARY

This report was prepared to fulfill two objectives. The first objective was to review the literature and analyse historic Canadian data pertenant to the identification of bluefin tuna, especially when sampled in a dressed condition. The identification of whole tuna is not a difficult procedure and can be accomplished by anyone using a standard taxonomic 'key'. Fish in a dressed or semi-processed state require more effort and depending on the size of the fish possibly some chemical laboratory analysis. Work is required to confirm that the lateral pockets found in the body cavity of the bluefin are not found in other species.

The second objective was to provide conversion factors for dressed to round fish. These factors will allow the use of the limited biological sampling data that are available to be incorporated into the international assessment process of ICCAT. In association with this latter objective an appendix of definitions and measures that should be taken for tuna have been provided. This will allow individual field officers to measure tuna and report their data in a standard format.

If readers wish to investigate relationships not covered in this report there is substantial raw data presented in two reports by M. Butler (Bultler, 1971; Butler, MS 1975).

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Appendix I

Taxonomic Key to the Scombrids of Canadian Atlantic Waters (from Scott and Scott, 1988)

Note: page numbers refer to Scott and Scott (1988).

1 Dorsal fin separated by a distance greater than snout length; dorsal fin spines about 9-12 — 2

Dorsal fins separated by a distance less than snout length; dorsal fin spines about 11-26 — 4

2 Dorsal finlets 8 or 9; anal finlets 7; a median keel on each side of caudal peduncle
- **bullet mackerel, <u>Auxis</u> <u>rochei</u> (p.448)**

Dorsal and anal finlets (each) 5; no median keel on caudal peduncle — 3

3 Dorsal fin spines 11 or 12; no swim bladder
- **Atlantic mackerel, <u>Scomber</u> <u>scombrus</u> (p.452)**

Dorsal fin spines 9 or 10; swim bladder present
- **chub mackerel, <u>Scomber</u> <u>japonicus</u>** (p.452)

4 Dorsal spines 20-23; dark oblique dorsal stripes extending below lateral line; small, usually less than 5 kg in weight
- **Atlantic bonito, <u>Sarda</u> <u>sarda</u> (p.451)**

Dorsal spines 11-19; no dark oblique bars extending below lateral line; variable in size, usually over 5 kg in weight — 5

5 Gill rakers 7-16; dorsal spines 12-19 (Spanish mackerels, Scomberomorus spp.) — 11

Gill rakers 25-63; dorsal spines 10-16 — 6

6 Gill rakers 53-63; dorsal spines 14-16; 3-5 dark longitudinal stripes on sides of abdomen
- **skipjack tuna, <u>Katsuwonus</u> <u>pelamis</u> (p.450)**

Gill rakers 25-45; dorsal spines 11-14 (rarely 15); no dark longitudinal stripes on abdomen — 7

7 Gill rakers 37-45; several black spots below pectoral fin; back with blue-green striped markings between dorsal fin bases and lateral line
- **little tunny, Euthynnus alletteratus (p.449)**

Gill rakers 23-43; no black spots below pectoral fin; no striped markings on back; dorsal fin spines 11-14; large fishes (tunas, Thunnus spp.) 8

8 Gill rakers 34-43; pectoral fin short, its length less than 80 percent of head length
- **bluefin tuna, Thunnus thynnus (p.459)**

Gill rakers 23-34; pectoral fin longer, its length over 80 percent of head length 9

9 Second dorsal and anal fins geratly extended, especially on specimens 120 cm TL or larger; ventral surface of liver without striations; gill rakers 26-34
- **yellowfin tuna, Thunnus albacares (p.457)**

Second dorsal and anal fins not greatly extended; ventral surface of liver with striations; gill rakers 25-31 10

10 Caudal fin with narrow white margin; pectoral fin longer, extending beyond 2nd dorsal; greatest body depth below or slightly ahead of 2nd dorsal fin
- **albacore, Thunnus alalunga (p.456)**

Caudal fin without white border; pectoral fin of moderate length, not reaching insertion of 2nd dorsal; greatest body depth near middle of 1st dorsal fin
- **bigeye tuna, Thunnus obesus (p.458)**

11 First dorsal fin black anteriorly; sides with 2 or 3 rows of roundish dark spots, yellow- to orange- colored in life; lateral line gently curved; dorsal spines 17-19
- **Spanish mackerel, Scomberomorus maculatus (p.456)**

First dorsal fin not black anteriorly; sides silvery, without spotting; lateral line with marked downcurve under 2nd dorsal; dorsal spines 15-18
- **king mackerel, Scomberomorus cavalla (p.455)**

Appendix II

Glossary of Standard Morphometric Terms

Note: See Appendix VI for a description of sampling methodology for Canadian bluefin tuna.
See Figure 3 for locations of many of these terms.

All measurements should be straight line whenever possible, otherwise follow the curve of the fish. Straight line measures can often be made by marking the distances on the floor and then measuring between these marks. If the fish is partially dressed then make as many different measurements as possible. If weights are available they should be recorded, round (or live) weight is preferable to dressed weight, however for any data records it is vital to note whether the lengths are straight (s) or curved (c) and if the weight is round (r) or dressed (d).

Body depth (fin): The straight line depth of the body at the anterior part of the base of the fin (anal, dorsal (1st or 2nd), pectoral, or pelvic).

Caudal keel: Boney lateral protrusions near the base of the caudal fin (on the caudal peduncle)
Caudal peduncle: Narrow part of the body immediately anterior to the caudal fin.
Caudal spread: The distance between the two tips of the tail spread in the natural position.

Dorsal-anal length: The straight length from the anterior part of the base of the 1st dorsal fin to the anterior part of the base of the anal fin.
Dressed Length: The straight line measure from the stump of the caudal peduncle to the posterior most edge of the cleithral arch, measured on a gutted, head and tail removed carcass.

Eye Diameter: Greatest distance measured across the cornea between the cartilaginous margins of the eyeball (also see orbit).

Finlets: Small dorsal or anal fins located between the caudal fin and the second dorsal fin or the anal fin.
Fin Base Length: The length from the anterior to the posterior part of the base of the fin (anal, dorsal (1st or 2nd),pectoral, or pelvic).
Fin length or height: The length from the most anterior part of the base of the fin (anal, dorsal (1st or 2nd), pectoral, or pelvic fin) to the most distant part of the fin.
Fin spines: Sharp pointed structures that support the first dorsal fin.
Fin rays: Soft structures that support the fins (serve similar function to spines).

Flank Length: Curved measure from tip of the upper jaw to middle of the fork in the caudal fin.
Fork Length: Straight line measure from tip of the upper jaw to middle of the fork in the caudal fin.

Half Girth: Curved measure of deepest part of body.
Head Length: Measurement from tip of upper jaw to posterior bony tip of the operculum.

Least body depth (caudal peduncle): The minimum depth of the fish just anterior of the tail.

Maximum body depth: The straight line depth of the body at its widest point.
Maxillary length: The length from the tip of the upper jaw to the farthest point of the mouth opening.

Orbit diameter: The maximum width of the boney eye socket (see also eye).

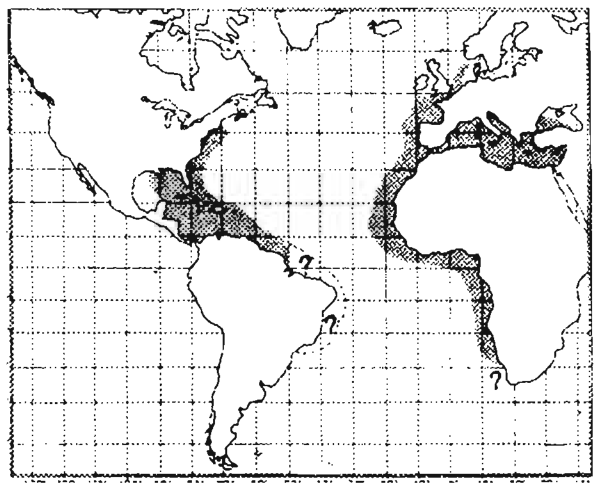
Pre-fin length: The length from the anterior part of the base of the fin (anal, dorsal (1st or 2nd), pectoral, or pelvic fin) to the tip of the upper jaw.

Appendix III

Description of the Six Tuna Species Known to Occur in Canadian Atlantic Waters (adapted from Collette and Nauen, 1983)

Little tunny - Euthynnus alleteratus (Rafinesque, 1810)

Little tunny are found in tropical and subtropical waters of the Atlantic (including the Mediterranean, Black, and Carribean Seas and the Gulf of Mexico). Other species in the Euthynnus are found in Pacific Ocean. This species is only rarely found within the Canadian EEZ.

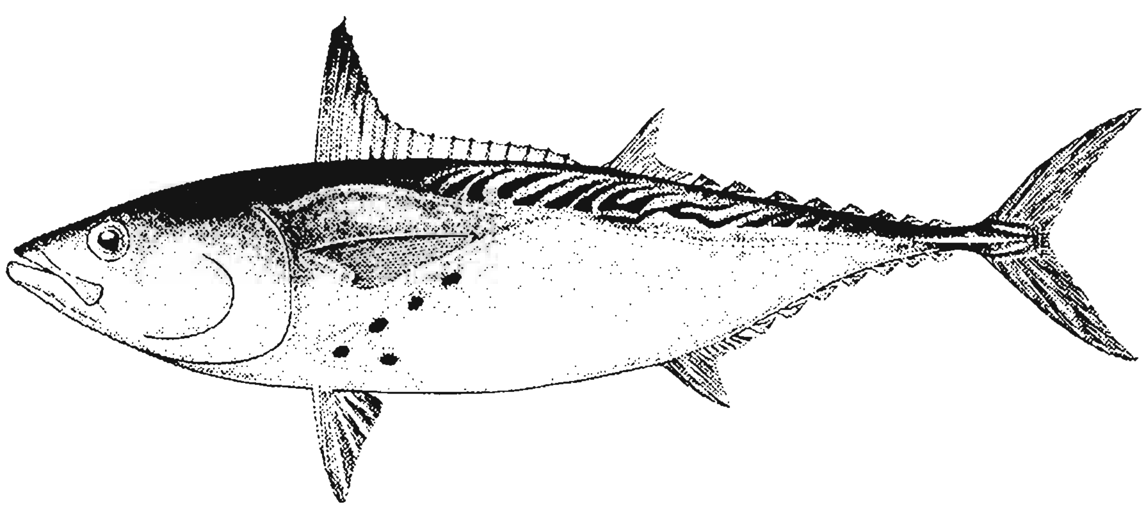


World distribution of little tunny.

Little tunny are epipelagic (living at depths of 0 to 200 m) and neritic (living in coastal waters) and are most abundant in inshore waters. They tend to school with other small tuna at certain times of the year but at other times they are scattered. Little tunny spawn in the summer season when the water is the warmest.

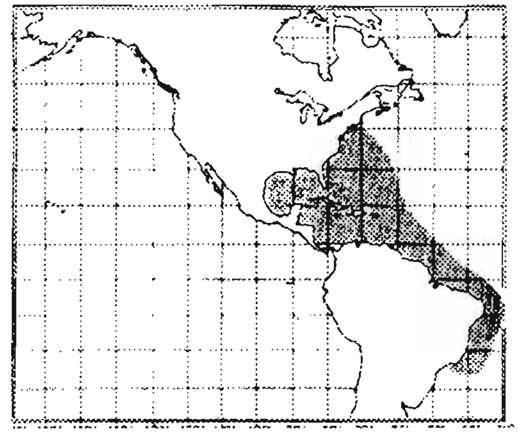
The number of gill rakers (37 to 45) separates the little tunny from all the tunas found in the northwest Atlantic except the bluefin. These fish have 11 to 15 anal fin rays. Dorsal markings are composed of broken horizontal stripes or bars. The pectoral fin is short as in the bluefin at about 15 to 18 % of fork length. Little tunny grow to about 100 cm in the Mediterranean, and reach maturity at about 35 cm off Florida. Commercial catches are composed of mostly 30 to 80 cm fish.

Little tunny are of minor commercial importance in the world tuna fisheries with total catches of 3,000 to 10,000 tonnes. They are of no commercial importance within the Canadian EEZ. In many parts of the world little tunny are often caught in mixed species inshore fisheries.

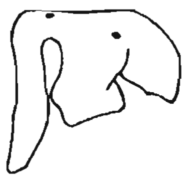


Blackfin tuna - Thynnus atlanticus (Lesson, 1830)

This species has a limited distribution restricted to the western Atlantic, common from Cape Cod, USA to Rio de Janeiro, Brazil. It only rarely occurs in summer in warm water within the Canadian EEZ.

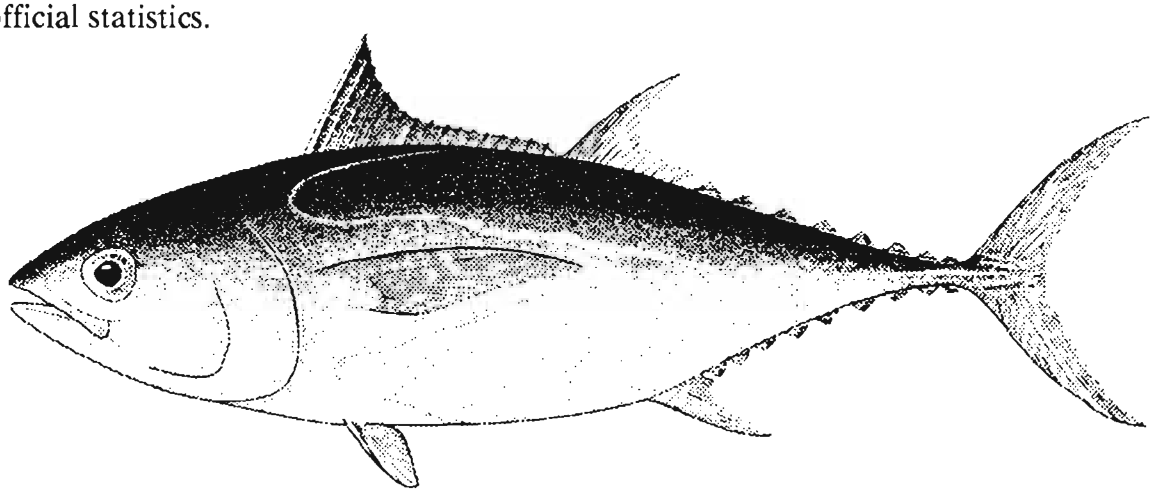

World distribution of blackfin tuna.

Blackfin tuna are epipelagic (living at depths of 0 to 200 m) in waters of at least 20 C. Blackfin often occur in mixed schools with skipjack tuna. Spawning is believed to occur in the tropical offshore waters between April and November, in the Gulf of Mexico spawning occurs between June and September.


liver

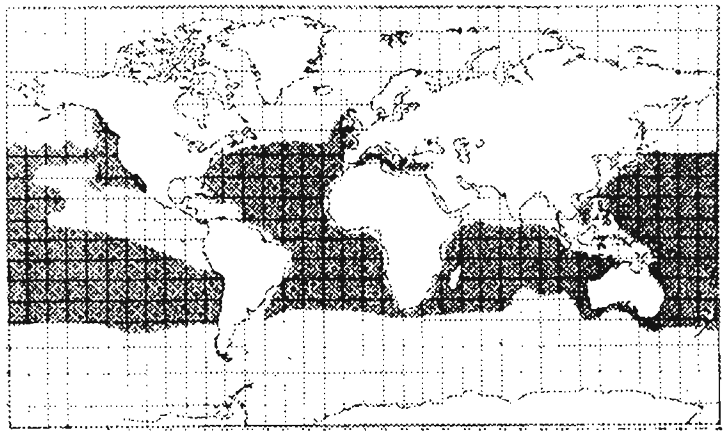
This small species of tuna is deepest near the middle of the first dorsal fin. The blackfin has few gill rakers (19 to 25) which will often separate it from the four common tuna of the Canadian EEZ. Pectoral fins are of moderate length (22 to 31 % of fork length) separating the blackfin from bluefin tuna. The ventral surface of the liver is smooth (no striations due to blood vessels), and the right lobe (when viewed from the top) is longer than the left or center lobe. . The finlets are dark with only a trace of yellow.

The only commercial fisheries for blackfin tuna are local with small catches. The highest annual landings worldwide was about 850 tonnes with annual catches generally less than 500 tonnes. Many of the fisheries exploiting this species are mixed with skipjack. As these species are not separated the true landings of blackfin could be significantly higher than that reported in official statistics.



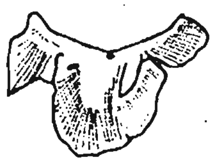
Albacore tuna - Thunnus alalunga (Bonnaterre, 1788)

This species lives in tropical and warm temperate zones of both the Atlantic (including the Mediterranean Sea) and Pacific Oceans. At least two stocks (north and south) are believed to live in each ocean. These stocks have distinct spawning areas with little or no interchange.



World distribution of albacore tuna

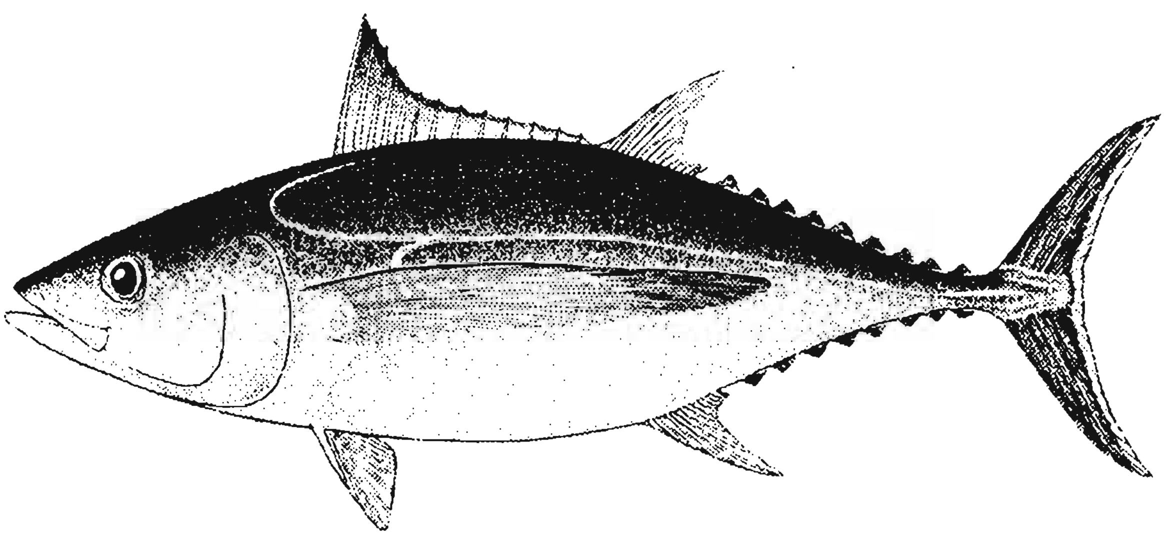
The albacore is epipelagic (living at depths of 0 to 200 m) and mesopelagic (living at depths of 200 to 1000 m). In the Pacific, albacore are found to depths of nearly 400 m while in the Atlantic they are found to 600 m. They are abundant in surface waters from 15 C to 20 C, deep swimming albacore can be found in water from 13 C to 25 C. Although widely distributed they tend to concentrate along thermal fronts.



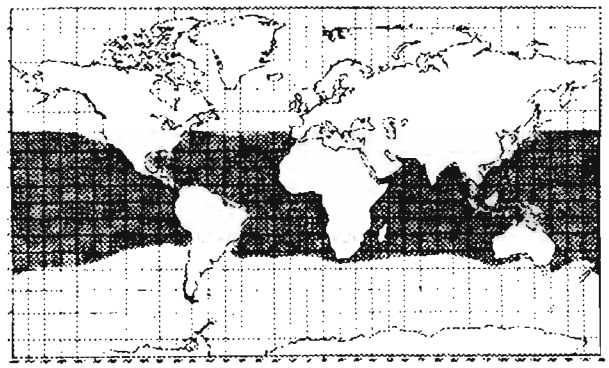
liver

Albacore are the smallest of the four common commercial tuna found within the Canadian EEZ. It is deepest (in cross section) at a more posterior point than any other tuna (just anterior to the second dorsal fin). The pectoral fin of fish caught within the Canadian EEZ is usually >30 % of the fork length. The ventral surface of the liver is striated with blood vessels and the three lobes are equal or the central lobe is slightly longer.

Although not internationally managed in the Atlantic at present, the albacore fisheries are considered to be over exploitation. Worldwide landings have declined from about 250,000 tonnes in 1974 to about 100,000 tonnes in recent years. ICCAT is upgrading its data analysis capacity to permit international assessments to be conducted on Atlantic albacore.

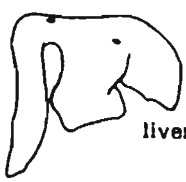


Yellowfin tuna - Thunnus albacares (Bonnaterre, 1788)


World distribution of yellowfin tuna.

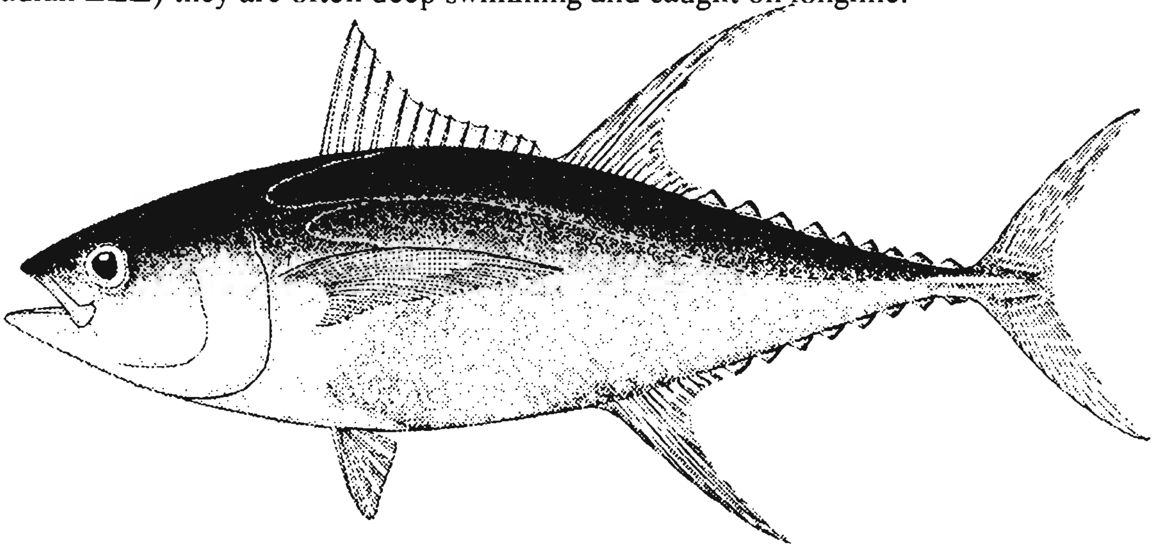
Yellowfin are widely distributed throughout the tropical and sub-tropical waters of the Atlantic, Pacific and Indian Oceans. It is absent from the Mediterranean Sea. Although the accompanying map does not show yellowfin present in the waters of the Canadian EEZ, they comprised 12 to 18 % of the catch of Canadian offshore longline vessels within the EEZ between 1987 and 1989.

Yellowfin are epipelagic (living at depths of 0 to 200 m) and oceanic. They live above and below the thermocline in water temperatures ranging from 18 C to 31 C. Yellowfin require water with oxygen levels above 2 ml/l and in some areas are confined to water above 100 m because of this. Schooling occurs in near surface waters, primarily by size, in either monospecific or multispecies schools. There is a lack of evidence of long distance migrations east - west or north - south, from this it is sometimes hypothesised that there may exist some discrete subpopulations.


liver

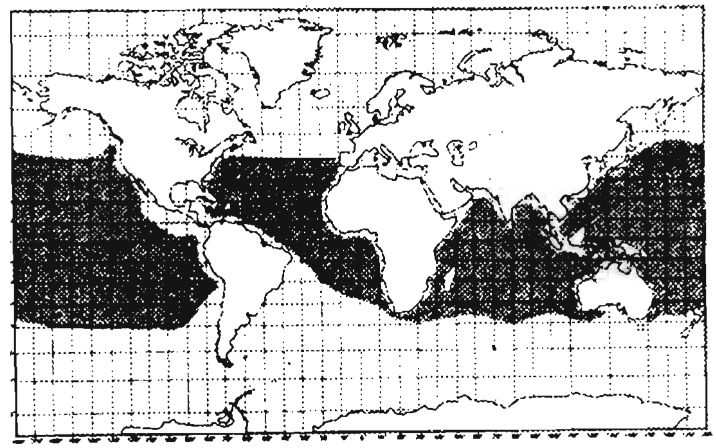
Adult yellowfin can often be identified from the other tuna found within the Canadian EEZ by the long dorsal and anal fins (can exceed 20 % of fork length).The pectoral fins are moderately long (22 to 31% of fork length). The ventral surface of the three lobed liver is smooth (no striations from blood vessels) and the right lobe (from the top) is longer than the other two. The finlets are bright yellow with a narrow black border.

Yellowfin are very important worldwide with catches of about 500,000 tonnes per annum. Decreasing CPUE indicate some stocks may be declining in abundance. Member countries of ICCAT are attempting to improve the database for west Atlantic yellowfin to enable a first analytic assessment to be conducted in the future. The largest catches are made with purse seine and pole and line fleets, however in the extremes of their range (ie. Canadian EEZ) they are often deep swimming and caught on longline.



Bigeye tuna - Thunnus obesus (Lowe, 1839)

This species is worldwide in distribution and is found in tropical and sub-tropical waters. Bigeye are found in the Atlantic, Pacific, and Indian Oceans but not in the Mediterranean Sea. Although not indicated on the accompanying map as occurring along the east coast of Canada, bigeye comprised a significant part (30 to over 50 %) of the offshore longline fisheries within the Canadian EEZ between 1987 and 1989. They are infact often the target species.

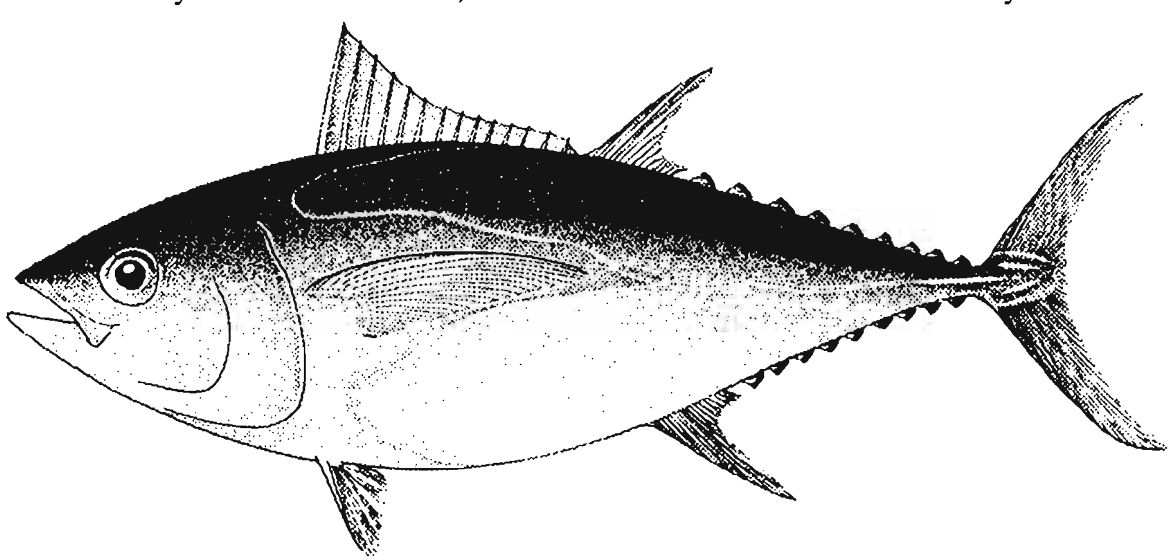


World distribution of bigeye tuna.

Bigeye tuna are epipelagic (living at depths of 0 to 200 m) and mesopelagic (living at depths of 200 to 1000 m), generally occurring above 250 m in depth. These fish have been found in waters from 13 C to 29 C but prefer 17 C to 22 C. Bigeye tend to be associated with the thermocline. Spawning takes place in the tropics between 10 N and 10 S.

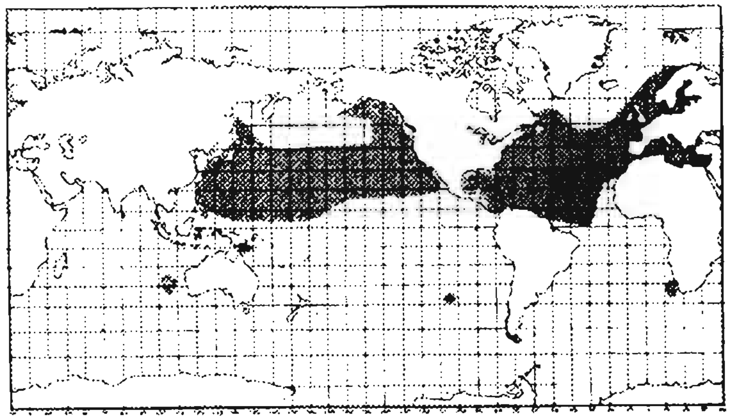
Bigeye are a large valuable commercial tuna species. The pectoral fin is medium length (22 - 31 % of fork length) on large (> 110 cm) fish; and very long (as long as on albacore) for individuals between 40 and 110 cm fork length. In fish over 30 cm the ventral surface of the liver is striated with blood vessels, the three lobes are equal in length or the central lobe may be longer.

Bigeye are not managed internationally and at present data are insufficient to conduct an analyltical assessment. As other species such as bluefin tuna are heavily exploited and catches are reduced, the valuable bigeye is being exploited at a higher level. World catches reached a peak in the early 1980's at about 200,000 tonnes and have declined in recent years.



Northern bluefin tuna - Thunnus thynnus (Linnaeus, 1758)

This species is composed of at least two sub-species. The T. thynnus thynnus is found within the Canadian EEZ and throughout the Atlantic Ocean, mostly in the northern half. The other subspecies, T. thynnus orientalis, is found only in the Pacific Ocean - also mostly in the northern half.

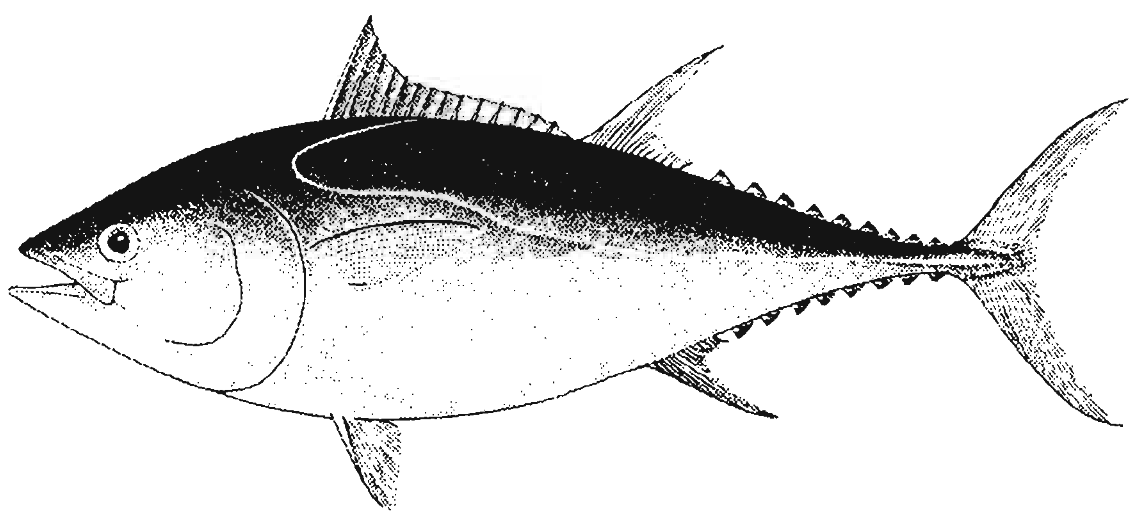


World distribution of bluefin tuna.

The Atlantic bluefin is epipelagic (liveing at depths of 0 to 200 m), usually oceanic but seasonally coming close to shore. Bluefin tuna can tolerate a wide range of water temperatures. Schooling is size specific up to 40 to 80 kg, sometimes with similar sized albacore, yellowfin, bigeye, and skipjack.

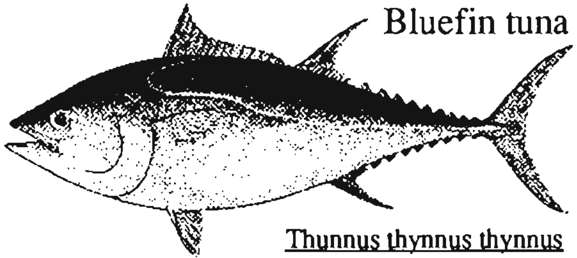
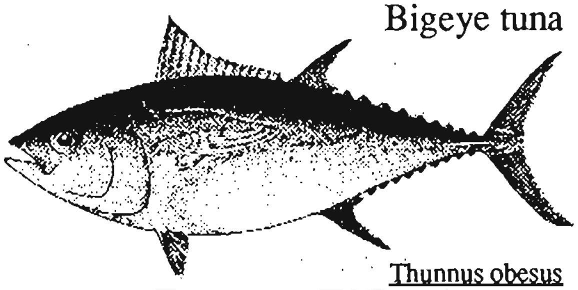
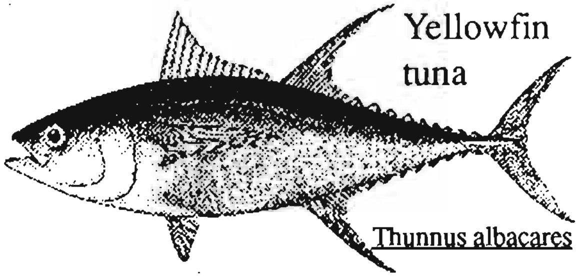
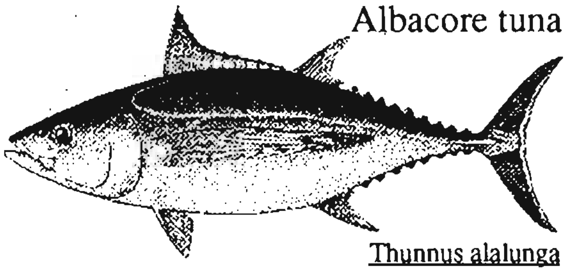
Atlantic bluefin can be identified from other tuna species found in the north Atlantic by the number of gill rakers (34 to 43) and the short pectral fin (17 to 22 % of fork length). The three lobed liver is striated with blood vessels on the ventral side and the three lobes are equal or the central lobe is slightly longer.

The Atlantic bluefin in the western Ocean is managed internationally by quota, size limits and closed season/area. The quota has been 2660 tonnes (Canada's share has been 573 tonnes) since 1982. The various management measures have reduced the rate of decline and some optimistic signs have been noted, however the results of these severe limitations have not been as beneficial as was originally hoped.



Appendix IV

Synopsis of some identification characters of four tuna species within the Canadian EEZ.

SPECIES	Gill Raker Range	Pectoral Fin Length	Liver	Maximum Length	Maximum Weight	Finlet Colour
Bluefin tuna  Thunnus thynnus thynnus	34 - 43	17 - 22 % of fork length Short	Bottom surface streaked. Three lobes equal or mid-lobe slightly longer.	305cm	1500kg	Dusky yellow edged with black.
Bigeye tuna  Thunnus obesus	23 - 31	22 - 31 % of fork length Medium	Bottom surface streaked. Three lobes equal or mid-lobe slightly longer.	235cm	200kg	Bright yellow edged with black.
Yellowfin tuna  Thunnus albacares	26 - 35	22 - 31 % of fork length Medium	Bottom surface smooth. Right (viewed from top) lobe longer than other two.	210cm	180kg	Bright yellow edged with black.
Albacore tuna  Thunnus alalunga	23 - 31	> 30 % of fork length Long	Bottom surface streaked. Three lobes equal or mid-lobe slightly longer.	130cm	40kg	Anal finlets dark, 1 or 2 may have yellow center. Dorsal finlets may have yellow in center.

Appendix V

Conversion factors of other species commonly found in the longline fisheries of the Canadian EEZ.

Table V.1.a. Monthly length and weight relationships from Atlantic bigeye tuna (Thunnus obesus, Lowe) collected by the IOP during 1988 and 1989 on longline vessels within the Canadian EEZ. Predicted weight for a 150 cm bigeye is given for each regression equation. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) / round weight (RW)

January: mean weight of 150 cm bigeye 57.9 kg
(FL) {60-185 cm} (RW) {6-100 kg}

RW (kg) = 0.20056×10^{-3} x FL (cm)$^{2.50920}$; n=569; r^2=0.81

February: mean weight of 150 cm bigeye 53.4 kg
(FL) {79-190 cm} (RW) {6-96 kg}

RW (kg) = 0.34282×10^{-4} x FL (cm)$^{2.84564}$; n=354; r^2=0.92

August: mean weight of 150 cm bigeye 68.3 kg
(FL) {71-147 cm} (RW) {4-60 kg}

RW (kg) = 0.24525×10^{-4} x FL (cm)$^{2.96169}$; n= 292; r^2=0.96

September: mean weight of 150 cm bigeye 67.4 kg
(FL) {52-178 cm} (RW) {3-110 kg}

RW (kg) = 0.29990×10^{-4} x FL (cm)$^{2.91871}$; n=1552; r^2=0.96

October: mean weight of 150 cm bigeye 59.4 kg
(FL) {56-185 cm} (RW) {4-120 kg}

RW (kg) = 0.10767×10^{-3} x FL (cm)$^{2.63845}$; n=1643; r^2=0.95

November: mean weight of 150 cm bigeye 61.8 kg
(FL) {60-203 cm} (RW) {5-131 kg}

RW (kg) = 0.17983×10^{-3} x FL (cm)$^{2.54419}$; n=7923; r^2=0.82

December: mean weight of 150 cm bigeye 61.3 kg
(FL) {69-172 cm} (RW) {6-118 kg}

RW (kg) = 0.17292×10^{-4} x FL (cm)$^{3.00967}$; n= 505; r^2=0.77

Annual combined estimate:
(FL) {60-273 cm} (RW) {4-412 kg}

RW (kg) = 0.49535×10^{-4} x FL (cm)$^{2.80874}$; n=4932; r^2=0.90

Table V.1.b. Length and weight relationships from Atlantic bigeye tuna (Thunnus obesus, Lowe) collected by the Scotia Fundy IOP during 1989 on longline vessels in the northwest Atlantic. These samples were collected in January, February, November and December. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) {70-185 cm} : dressed weight (DW) {5-80 kg}

$$DW\ (kg) = 0.62189\times10^{-4} \times FL\ (cm)^{2.69113};\ n=2429;\ r^2=0.77$$

$$FL\ (cm) = 48.17258 \times DW\ (kg)^{0.28586};\ n=2429;\ r^2=0.77$$

Fork length (FL) {78-290 cm} : dressed length (DL) {68-258 cm}

$$DL\ (cm) = -6.80710 + 0.89852 \times FL\ (cm);\ n=344;\ r^2=0.98$$

$$FL\ (cm) = 7.57589 + 1.11294 \times DL\ (cm);\ n=344;\ r^2=0.98$$

Dressed length (DL) {55-156 cm} : round weight (RW) {6-94 kg}

$$RW\ (kg) = 0.13541\times10^{-3} \times DL\ (cm)^{2.66069};\ n=344;\ r^2=0.86$$

$$DL\ (cm) = 35.87354 \times RW\ (kg)^{0.31044};\ n=344;\ r^2=0.86$$

Dressed length (DL) {55-156 cm} : dressed weight (DW) {5-80 kg}

$$DW\ (kg) = 0.10512\times10^{-3} \times DL\ (cm)^{2.67943};\ n=344;\ r^2=0.86$$

$$DL\ (cm) = 35.99967 \times DW\ (kg)^{0.32094};\ n=344;\ r^2=0.86$$

Dressed weight (DW) {5-80 kg} : round weight (RW) {6-94 kg}

$$RW\ (kg) = -4.02289 + 1.17491 \times DW\ (kg);\ n=3509;\ r^2=0.99$$

$$DW\ (kg) = 0.03424 + 0.85113 \times RW\ (kg);\ n=3509;\ r^2=0.99$$

Table V.2.a. Length and weight relationships from Atlantic yellowfin tuna (Thunnus albacarus, Bonnaterre) collected by the IOP during 1988 and 1989 on longline vessels within the Canadian EEZ. Predicted weight for a 125 cm yellowfin is given for each regression equation. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) / round weight (RW)

January: mean weight of 125 cm yellowfin 32.8 kg
(FL) {71-154 cm} (RW) {8-60 kg}

RW (kg) = 0.22468×10^{-3} x FL (cm)$^{2.46285}$; n= 17; $r^2=0.87$

February: mean weight of 125 cm yellowfin 28.4 kg
(FL) {77-135 cm} (RW) {5-35 kg}

RW (kg) = 0.10338×10^{-3} x FL (cm)$^{2.59361}$; n=170; $r^2=0.73$

August: mean weight of 125 cm yellowfin 33.6 kg

RW (kg) = 0.57176×10^{-4} x FL (cm)$^{2.75095}$; n= 33; $r^2=0.97$

September: mean weight of 125 cm yellowfin 28.4 kg
(FL) {62-180 cm} (RW) {5-82 kg}

RW (kg) = 0.74908×10^{-5} x FL (cm)$^{3.13758}$; n= 571; $r^2=0.91$

October: mean weight of 125 cm yellowfin 34.3 kg
(FL) {72-183 cm} (RW) {5-84 kg}

RW (kg) = 0.99702×10^{-4} x FL (cm)$^{2.64043}$; n=7183; $r^2=0.81$

November: mean weight of 125 cm yellowfin 33.4 kg
(FL) {73-163 cm} (RW) {8-73 kg}

RW (kg) = 0.18567×10^{-2} x FL (cm)$^{2.02936}$; n=1370; $r^2=0.58$

December: one yellowfin caught

128 cm 34 kg n = 1

Annual combined estimate:
(FL) {62-183 cm} (RW) {5-84 kg}

RW (kg) = 0.31392×10^{-4} x FL (cm)$^{2.87141}$; n=1119; $r^2=0.95$

Table V.2.b. Length and weight relationships from Atlantic yellowfin tuna (Thunnus albacarus, Bonnaterre) collected by the Scotia Fundy IOP during 1989 on longline vessels in the northwest Atlantic. These samples were collected in January, February, November and December. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) {62-175 cm} : dressed weight (DW) {4-65 kg}

$DW\ (kg) = 0.13156\times10^{-4} \times FL\ (cm)^{2.98144}$; n=644; r^2=0.90

$FL\ (cm) = 48.37775 \times DW\ (kg)^{0.30100}$; n=644; r^2=0.90

Fork length (FL) {80-130 cm} : dressed length (DL) {65-110 cm}

$DL\ (cm) = -3.13805 + 0.87290 \times FL\ (cm)$; n=42; r^2=0.92

$FL\ (cm) = 13.24235 + 1.04842 \times DL\ (cm)$; n=42; r^2=0.92

Dressed length (DL) {65-110 cm} : round weight (RW) {14-29 kg}

$RW\ (kg) = 0.13752 \times DL\ (cm)^{1.12719}$; n=42; r^2=0.43

$DL\ (cm) = 28.89908 \times RW\ (kg)^{0.38494}$; n=42; r^2=0.43

Dressed length (DL) {65-110 cm} : dressed weight (DW) {12-25 kg}

$DW\ (kg) = 0.10870 \times DL\ (cm)^{1.14237}$; n=42; r^2=0.43

$DL\ (cm) = 31.30757 \times DW\ (kg)^{0.37953}$; n=42; r^2=0.43

Dressed weight (DW) {4-65 kg} : round weight (RW) {5-78 kg}

$RW\ (kg) = 1.14538 + 1.16396 \times DW\ (kg)$; n=743; r^2=0.99

$DW\ (kg) = -0.08830 + 0.85806 \times RW\ (kg)$; n=743; r^2=0.99

Table V.3. Length and weight relationships from Atlantic albacore tuna (Thunnus alalunga, Bonnaterre) collected by the IOP during 1988 and 1989 on longline vessels within the Canada EEZ. Predicted weight for a 100 cm albacore is given for each regression equation.The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) / round weight (RW)

January: mean weight of 100 cm albacore 19.9 kg
(FL) {50-118 cm} (RW) {3-33 kg}

RW (kg) = 0.10162×10^{-4} x FL (cm)$^{3.14550}$; n= 631; r^2=0.89

February: mean weight of 100 cm albacore 20.9 kg
(FL) {58-118 cm} (RW) {5-36 kg}

RW (kg) = 0.25131×10^{-4} x FL (cm)$^{2.95955}$; n= 548; r^2=0.88

August: mean weight of 100 cm albacore 20.7 kg
(FL) {61-122 cm} (RW) {7-33 kg}

RW (kg) = 0.28227×10^{-3} x FL (cm)$^{2.43227}$; n= 40; r^2=0.66

September: mean weight of 100 cm albacore 20.3 kg
(FL) {86-126 cm} (RW) {9-32 kg}

RW (kg) = 0.35286×10^{-4} x FL (cm)$^{2.87977}$; n= 170; r^2=0.83

October: mean weight of 100 cm albacore 19.6 kg
(FL) {46-125 cm} (RW) {3-30 kg}

RW (kg) = 0.24081×10^{-4} x FL (cm)$^{2.95500}$; n= 521; r^2=0.82

November: mean weight of 100 cm albacore 20.1 kg
(FL) {19-130 cm} (RW) {1-36 kg}

RW (kg) = 0.49402×10^{-4} x FL (cm)$^{2.80488}$; n= 297; r^2=0.87

December: mean weight of 100 cm albacore 19.4 kg
(FL) {70-129 cm} (RW) {7-37 kg}

RW (kg) = 0.13717×10^{-2} x FL (cm)$^{2.07548}$; n= 99; r^2=0.60

Annual combined estimate:
(FL) {19-130 cm} (RW) {1-37 kg}

RW (kg) = 0.25713×10^{-4} x FL (cm)$^{2.94485}$; n=2306; r^2=0.88

Note: dressed weight and dressed length conversions are not provided for albacore as this smaller species is normally filletted and not headed, gutted and tailed as are the other species.

Table V.4. Length and weight relationships from Atlantic swordfish(Xiphias gladius, L.) collected by the IOP during 1988 and 1989 on longline vessels within the CanadianEEZ. The predicted weight for a 150 cm swordfish is given for each regression equation. The range of sizes sampled is indicated in brace brackets after each heading.

Fork length (FL) / round weight (RW)

January: mean weight of 150 cm swordfish 44.0 kg
(FL) {78-260 cm} (RW) {3-285 kg}

RW (kg) = 0.58396×10^{-6} x FL (cm)$^{3.61977}$; n= 41; r^2=0.94

February: mean weight of 150 cm swordfish 42.2 kg
(FL) {74-200 cm} (RW) {5-127 kg}

RW (kg) = 0.34026×10^{-5} x FL (cm)$^{3.25934}$; n= 33; r^2=0.94

August:
(FL) {85-113 cm} (RW) {8-25 kg}

RW (kg) = 0.23902×10^{-6} x FL (cm)$^{3.87845}$; n= 3; r^2=0.85

September: mean weight of 150 cm swordfish 46.8 kg
(FL) {67-185 cm} (RW) {3-96 kg}

RW (kg) = 0.71577×10^{-6} x FL (cm)$^{3.59170}$; n= 20; r^2=0.95

October: mean weight of 150 cm swordfish 42.6 kg
(FL) {54-283 cm} (RW) {3-291 kg}

RW (kg) = 0.66078×10^{-6} x FL (cm)$^{3.58865}$; n= 86; r^2=0.94

November: mean weight of 150 cm swordfish 46.6 kg
(FL) {39-303 cm} (RW) {2-378 kg}

RW (kg) = 0.61757×10^{-6} x FL (cm)$^{3.62039}$; n= 81; r^2=0.96

December: mean weight of 150 cm swordfish 48.2 kg
(FL) {43-265 cm} (RW) {2-293 kg}

RW (kg) = 0.58410×10^{-6} x FL (cm)$^{3.17856}$; n= 33; r^2=0.89

Annual combined estimate:
(FL) {39-303 cm} (RW) {2-378 kg}

RW (kg) = 0.71894×10^{-6} x FL (cm)$^{3.58338}$; n= 296; r^2=0.95

Appendix VI

Sampling methodology for bluefin tuna caught along the east coast of Canada.

These instructions are a summary of the current sampling protocols used in the DFO from 1985 to 1991 (present). Many of the terms and definitions of the various measures have been defined in Appendix II. A copy of the sample data recording form follows. A summary of the data collected by the National Marine Fisheries Service (NMFS) (US) is provided in Prince and Lee (1982).

Size data: Length data are usually easier and more valuable to collect than weight data, however both are needed to provide a true picture of the size of a tuna. Fork length is preferred over flank length and round weight preferred over dressed weight.

All lengths should be measured in centimeters (to the nearest 0.5 cm), if necessary inches can be used (to the nearest 0.25 inch); in either case the units must be stated. Fork length is most accurately measured using a set of 3 m calipers. If calipers are not available, marks can be made on the floor (deck) and a straight line measure taken between the marks. The flank length is measured with a metal tape measure along the mid-lateral line. The tape is held in contact with the fish and passes under the pectoral fin and follows the caudal peduncle (not the caudal keel) to the fork in the tail.

All weights should be measured in kilograms (to the nearest 0.5 kg for fish under 100 kg and to the nearest kg for larger fish), or in pounds; however in either case the units must be stated. Record only weights that were actually measured. Do not record weights estimated or calculated from a conversion factor.

The **half maximum girth** is measured using a metal tape at the deepest part of the body. The tip of the tape is inserted into the dorsal fin groove and the tape runs halfway around the fish, in contact with the body, under the pectoral and pelvic fins to the mid-ventral point. This measurement must be perpindicular to the long axis (fork length) of the fish.

Sex determination: There are no reliable secondary sexual characteristics in bluefin tuna, thus sex determination requires gross examination of the gonads. The gonads of bluefin are normally paired structures that originate at the vent and extend anteriorly. Each gonad is held in place by mesentery and generally has fatty deposits associated with it. A spent or unripe giant bluefin (the most common in Canadian waters) has a gonad about 60 cm long and 6 cm in diameter. The fatty tissue associated with the gonad can be 1 to 3 times the size of the gonad.

The gonads are generally removed during the butchering process, with the rest of the viscera. This can make finding the gonads a difficult process. Once located the gonad should be examined in cross section using a sharp knife. It is important that the gonad and not the fatty tissue be examined.

The ovary appears round in cross section and has a single, large irregular central lumen. The inner surface is convoluted and the tissue often appears slightly granular. The testis appears flattened or triangular in cross section, it has no central lumen, although small ducts may be present. The tissue is relatively smooth and homogeneous in texture.

Otolith collection: The sagittal otoliths are the largest of the three pairs of otoliths and the ones most often used for age determination of fish. Otoliths can be removed from giant bluefin by cutting the skull with a hand saw or if several fish are to be sampled, use a chain saw or a reciprocating meat saw. To locate the otoliths draw a line on the operculum perpendicular to the longitudinal axis of the fish that just touches the anterior edge of the eye and the end of the upper jaw. Draw a second line parallel to the first, along the rear edge of the pre-operculum (Figure 3). Saw a vertical cut half way between these two lines, the otliths will normally be in the front portion of the cut head. In a giant bluefin this cut will usually be 7 to 10 cm from the posterior edge of the eye. (The procedure for locating and extracting the otoliths from a bluefin tuna is best learned from an experienced sampler.)

The otoliths are contained in semicircular canals that lie in two bilateral cavities just below the brain in the upper third of the head. Probe these cavities with forceps and gently locate and remove the otoliths. For a fish this large the otoliths are relatively small (ie. 2 cm for 250 to 300 kg fish). Bluefin otoliths are fragile, if the otolith breaks, keep both parts. Clean any extraneous tissue from the otoliths and store in a labelled envelope.

ATLANTIC BLUEFIN TUNA : SAMPLING DATA

dc 03 . 1988

Date ____ ____ ____ (day / month / year)

Sampler ________

Port of landing ________________

Name of vessel ________________ CFVN

Bluefin tag number ________________

WEIGHT: Round ________ LBS ________ KGS
Dressed ________ LBS ________ KGS

weight to nearest pound or kilogram

Dressed weight is gutted, head and tail removed - ready for shipping.

LENGTH: Fork (A) ________ INCH ________ CMS
Half girth (B) ________ INCH ________ CMS
Flank (C) ________ INCH ________ CMS
Trunk (D) ________ INCH ________ CMS

length to nearest half inch or whole centimeter

Flank length > Fork length > Trunk or Dressed length

SEX: _____ male/female

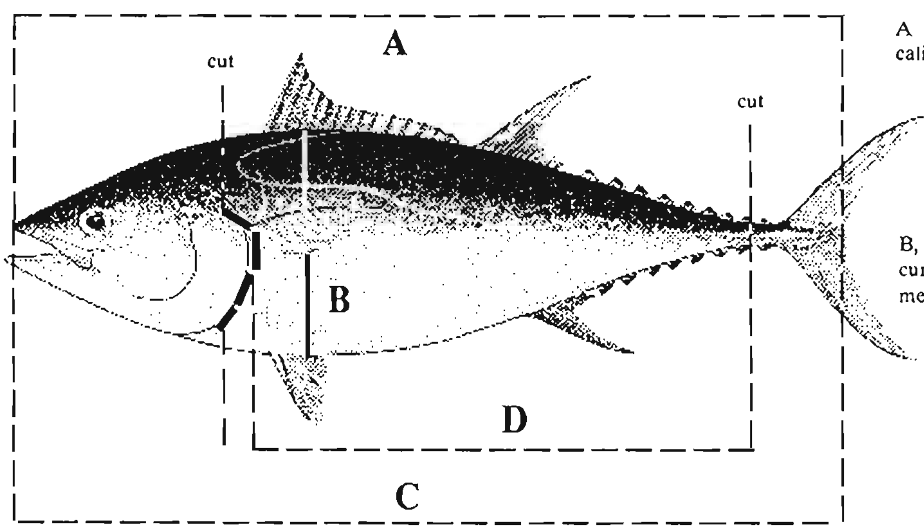
SAMPLES TAKEN:
flesh Y / N
gonad Y / N
parasites Y / N
otoliths Y / N
liver Y / N
stomach Y / N
other _____ Y / N

Gut contents: items / nos.

If in doubt as to species ID. record the following:
Gill raker count (first anterior arch) : _____
First dorsal fin length: ______ cm
Second dorsal fin length: ______ cm
Pectoral fin length: ______ cm
First pre-dorsal length: ______ cm
Second pre-dorsal length: ______ cm

Round weight and A, B, C on whole fish before butchering.

Dressed weight and D on fish after processing.



A is straight calipers measure

B, C, D are curved tape measures