Mercury in the Global Environment:

Tuna

A series publication by BRI's Center for Mercury Studies

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About Tuna

Cave paintings in Sicily document the importance of Atlantic bluefin tuna as a food source to coastal communities dating back to the Stone Age—and the ancient Greeks displayed its value by stamping it on their coins. For over 5,000 years, Haida Indians of the Pacific Northwest and Japanese fishermen have hunted Pacific bluefin tuna. Today, commercial tuna fishing is a $42+ billion global industry. High consumer demand means elevated mercury levels in some species pose a human health risk.

The 15 species of tuna in the tribe Thunnini range in size from a few kilograms up to 680 kg (nearly 1,500 pounds). Some species live only a few years, while others survive for decades. Their sleek body shape and retractable fins help make them swift swimmers; yellowfin tuna can reach speeds of 75 km/hour (47 miles/hour).

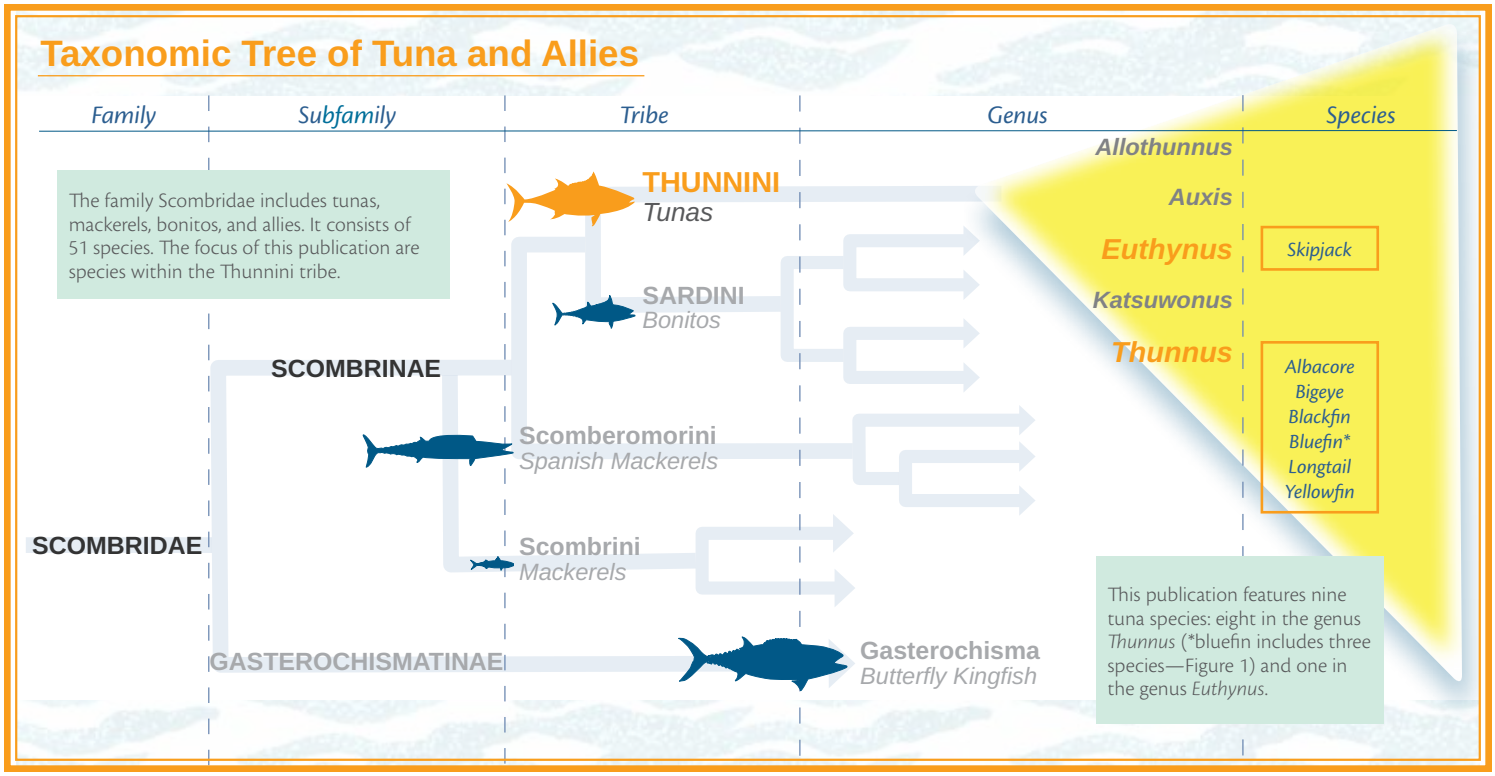
All tuna species share similar distinctive characteristics. The physiology of their respiratory systems require that they swim constantly, forcing water through their gills to oxygenate their blood. Their muscles continuously generate heat, allowing them to regulate body temperature. They can therefore tolerate both tropical and temperate waters worldwide.

Characteristics of tunas that explain their often elevated mercury levels:

- Tuna are top trophic-level predators that prey on other large fish, which accounts for the biomagnification of methylmercury (MeHg) in their food web.
- They migrate thousands of miles across oceans, which exposes them to mercury hotspots around the world.
- They are long-lived (up to 50 years for some species) and bioaccumulate mercury as they grow and age.

Commercial fishing of Atlantic bluefin tuna. Ernest Hemingway called the Atlantic bluefin "the king of all fish." Carl Linnaeus, the father of modern scientific classification, named the Atlantic bluefin *Thunnus thynnus*: tuna of tunas. All three species of bluefin tuna regularly contain MeHg levels above accepted guidelines for human consumption (Figure 2).

Taxonomic Tree of Tuna and Allies



Mercury in Tuna

Tuna are regularly listed on fish consumption advisories (Kaneko and Ralston 2007). Yet, tuna are consistently among the top five commodities in the global fish market. Skipjack, albacore, and yellowfin are most commonly processed for canned products, while bluefin are valued for direct consumption (Food and Agriculture Organization [FAO] 2018).

BRI's Global Biotic Mercury Synthesis (GBMS) database, together with associated FAO harvest data, indicate that skipjack tuna have the lowest mean mercury concentrations (Figure 1) among nine species sampled. Yellowfin and albacore tuna have average mercury concentrations that are slightly above the US-based consumption guideline of 0.22 parts per million (ppm). Atlantic and Pacific bluefin, bigeye, and blackfin tunas exceed the European Commission (EC) threshold guideline of 0.5 ppm. Bluefin tuna mercury levels are generally high, but vary by ocean basin (Figure 2).

Research estimates that present atmospheric mercury deposition rates will result in an approximate doubling of mercury concentrations by 2050, particularly in the North Pacific Ocean (Sunderland et al. 2009). New findings from Drevnick et al. (2015) show that mercury concentrations in yellowfin tuna near Hawaii are currently increasing at a rate ≥ 3.8 percent per year and are consistent with the atmospheric mercury cycling models for the North Pacific. Similar trends were also found for Hawaiian populations of bigeye tuna (Drevnick and Brooks 2017). Conversely, Atlantic bluefin tuna mercury concentrations have declined by 19 percent from 2004-2012 in the North Atlantic Ocean, which parallels comparably reduced atmospheric emissions rates in North America (Lee et al. 2016).

Bluefin by Ocean Basin

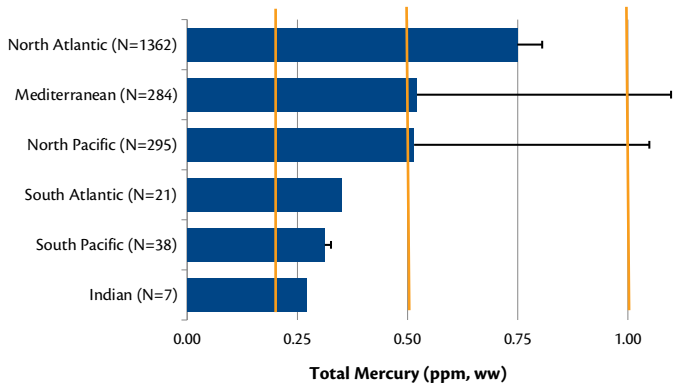


Figure 2. Average (± SD; N = sample size) THg concentration in muscle tissue of three bluefin tuna species (Atlantic, Pacific, and Southern bluefin) from six ocean regions.

FAO Harvest and Mercury in Tuna

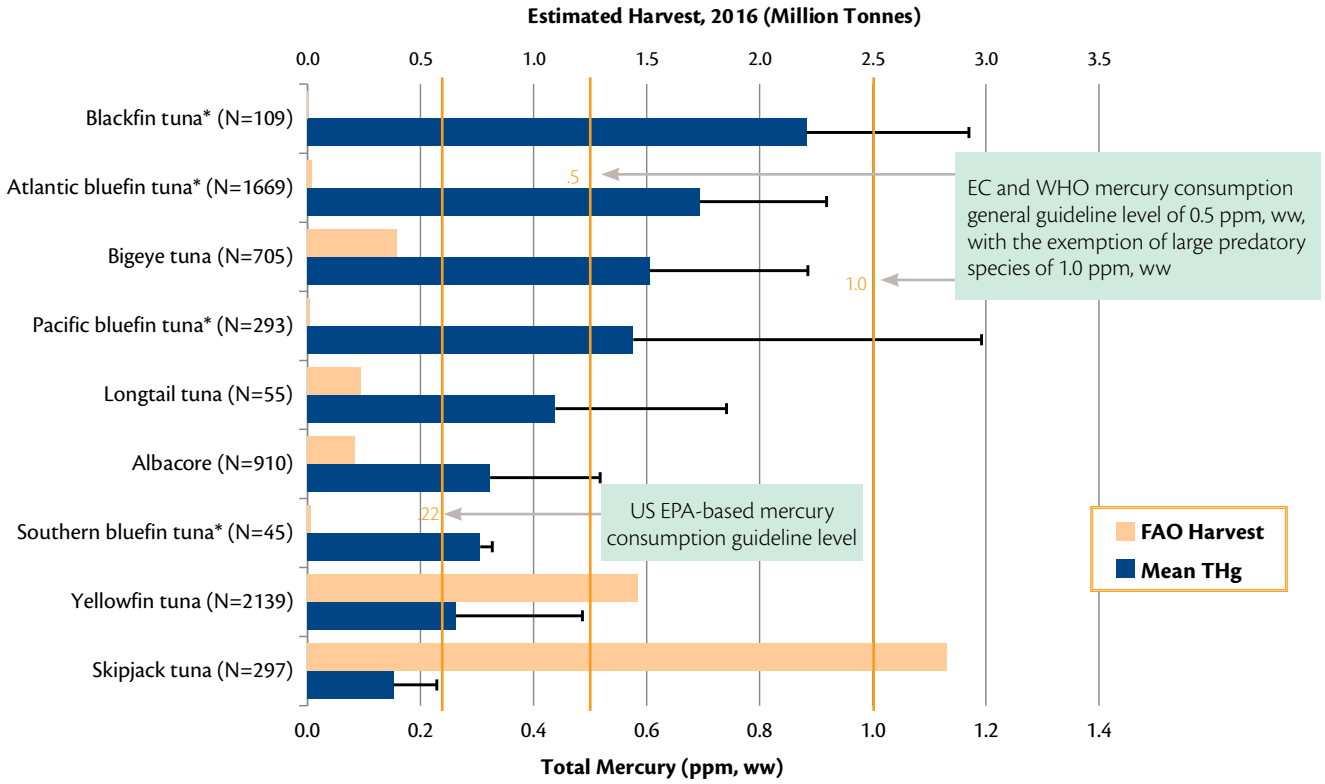


Figure 1. Average (± SD; N=sample size) total mercury (THg) concentration in muscle tissue of nine tuna species compared with the FAO harvest estimate in tonnes. See back page for mercury consumption guidelines. *FAO harvest is less than 15,000 tonnes.

International Union for Conservation of Nature (IUCN) Red List of Threatened Species

Five of the eight species of tuna are in the threatened or Near Threatened IUCN Red List Categories. These include: Southern Bluefin, Critically Endangered; Atlantic Bluefin, Endangered; Bigeye, Vulnerable; Yellowfin, Near Threatened; and Albacore, Near Threatened.

Canned tuna is the second most frequently consumed seafood product in the **US** (shrimp is first) at 2.7 pounds per person per year. The US catches less than 1% of the worldwide tuna harvest; over half their catch is albacore (FAO 2018). *Mercury concern: The three species most used in canning are skipjack (below 0.22 ppm, ww), yellowfin and albacore (above the 0.22 threshold).*

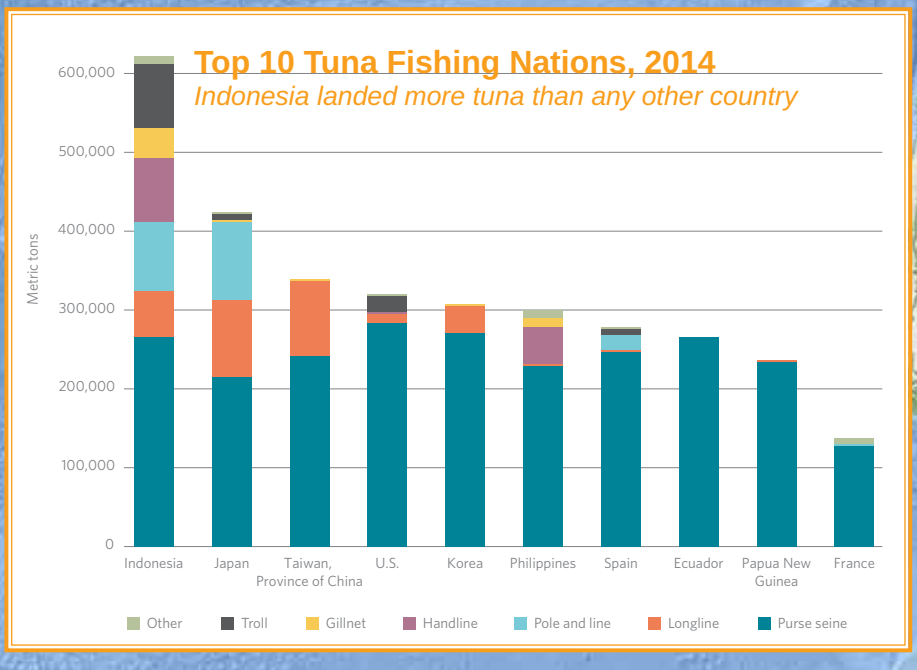
The majority of fishing in the **eastern Atlantic** is conducted with **purse seines**—large, vertically floating nets up to one mile long which are used to surround schools of fish. Once fish are netted, the base is drawn together, creating a purse. Purse seine catches are used to supply the 60+ tuna ranches in the Mediterranean Sea.[1]

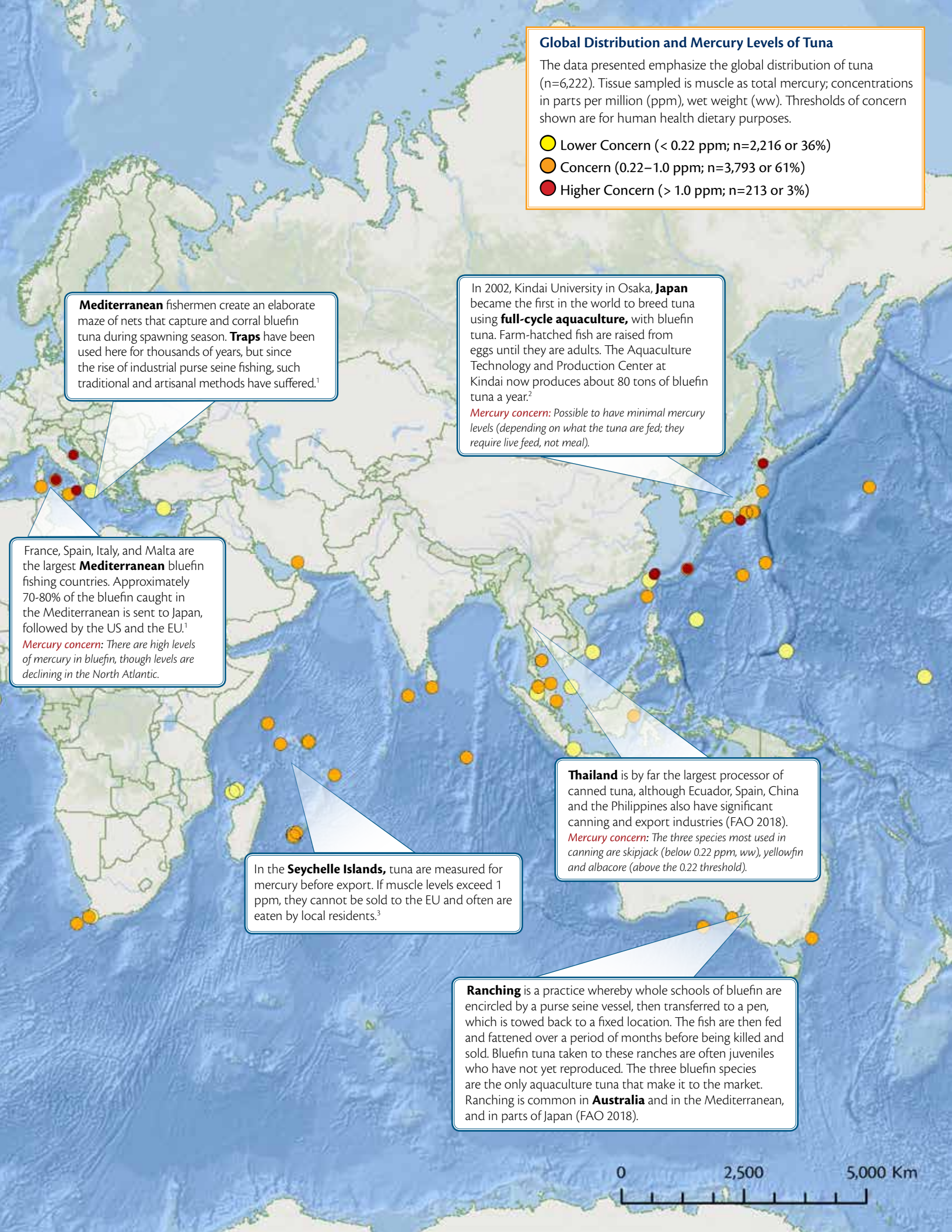
Bluefin Aquaculture Value/Production

Country/Region	Value (USD)	Tonnes
Japan	$366,458,200	13,413
Mediterranean	$102,307,690	6,909
Australia	$94,291,840	8,895
Mexico	$40,718,580	8,756

(FAO 2016)

Blackfin tuna are the only tuna not commercially harvested. They are a popular **sport fish** found in coastal areas in the western Atlantic from Massachusetts to **Brazil,** including the **Caribbean Sea**. *Mercury concern: Blackfin have the highest average level of mercury in the GBMS database.*




Global Distribution and Mercury Levels of Tuna
The data presented emphasize the global distribution of tuna (n=6,222). Tissue sampled is muscle as total mercury; concentrations in parts per million (ppm), wet weight (ww). Thresholds of concern shown are for human health dietary purposes.
Lower Concern (< 0.22 ppm; n=2,216 or 36%)
Concern (0.22–1.0 ppm; n=3,793 or 61%)
Higher Concern (> 1.0 ppm; n=213 or 3%)
Mediterranean fishermen create an elaborate maze of nets that capture and corral bluefin tuna during spawning season. Traps have been used here for thousands of years, but since the rise of industrial purse seine fishing, such traditional and artisanal methods have suffered.[1]
In 2002, Kindai University in Osaka, Japan became the first in the world to breed tuna using full-cycle aquaculture, with bluefin tuna. Farm-hatched fish are raised from eggs until they are adults. The Aquaculture Technology and Production Center at Kindai now produces about 80 tons of bluefin tuna a year.[2]
Mercury concern: Possible to have minimal mercury levels (depending on what the tuna are fed; they require live feed, not meal).
France, Spain, Italy, and Malta are the largest Mediterranean bluefin fishing countries. Approximately 70-80% of the bluefin caught in the Mediterranean is sent to Japan, followed by the US and the EU.[1]
Mercury concern: There are high levels of mercury in bluefin, though levels are declining in the North Atlantic.
Thailand is by far the largest processor of canned tuna, although Ecuador, Spain, China and the Philippines also have significant canning and export industries (FAO 2018).
Mercury concern: The three species most used in canning are skipjack (below 0.22 ppm, ww), yellowfin and albacore (above the 0.22 threshold).
In the Seychelle Islands, tuna are measured for mercury before export. If muscle levels exceed 1 ppm, they cannot be sold to the EU and often are eaten by local residents.[3]
Ranching is a practice whereby whole schools of bluefin are encircled by a purse seine vessel, then transferred to a pen, which is towed back to a fixed location. The fish are then fed and fattened over a period of months before being killed and sold. Bluefin tuna taken to these ranches are often juveniles who have not yet reproduced. The three bluefin species are the only aquaculture tuna that make it to the market. Ranching is common in Australia and in the Mediterranean, and in parts of Japan (FAO 2018).
0
2,500
5,000 Km

Life of Tuna in the Ocean

Journey to Market

Tuna are captured across the world's oceans from the North Atlantic to the South Pacific. Tuna catches are processed and shipped frozen. FAO commercial tuna catch for 2016 was 6 million tonnes. The canning industry is the main destination for most of the world's tuna catches, with sushi and sashimi production as the secondary outcome.

Capture Methods in the Wild

- Longline fishing (pictured)
- Purse seine net (pictured)
- Hand-operated, pole-and-line (often in association with Fish Aggregating Devices—FADs—floating devices that attract fish)
- Ranching

Atlantic Bluefin

Bigeye (4)

Yellowfin (3)

Albacore

Skipjack

Food Web

Tuna are long-lived, top trophic-level (apex) predators. Apex predators tend to be large, fast, and efficient at catching prey. Tuna feed on multiple food webs, which may have coastal, benthic (bottom-dwelling), demersal (near bottom-dwelling), or pelagic (open ocean) origins. Common prey items include small crustaceans, squid, and pelagic fish. Even very large species eat from the bottom up on the food web, however, the maximum size (and trophic level) of prey items is generally relative to the size of the tuna.

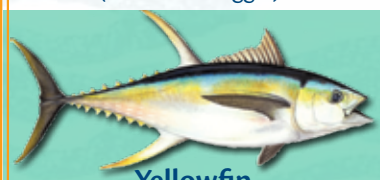
Biomagnification of Methylmercury (MeHg)

Inorganic mercury (Hg) from emissions and point sources is deposited into the ocean, where mercury can rapidly methylate and enter the food web.

1. Mercury is methylated by bacteria in the water column and absorbed by phytoplankton.
2. Methylmercury in phytoplankton is eaten by zooplankton, representing many size classes—beginning a process called biomagnification.
3. Biomagnification of MeHg continues up the food web to top trophic-level predators, such as tuna.
4. Methylmercury can bioaccumulate in individuals as they grow and age (e.g., older large tuna have higher MeHg levels than young small tuna).

(2)

(1)

TUNA SPECIES[4]	LIFE HISTORY/RANGE	SIZE (common length and max. length)	LIFESPAN (max.)	COMMON FOOD PRODUCT	MERCURY CONCERN LEVEL*
 **Skipjack** *(Katsuwonus pelamis)*	Reproduce early (first year) and often. Found mainly in the tropical areas of the Atlantic, Indian, and Pacific Oceans. Most abundant in equatorial waters. Feed on fish, crustaceans, cephalopods, and molluscs.	80cm. (2.6 ft) 110 cm. (3.6 ft)	~12 years	Canned light tuna	
 **Blackfin** *(Thunnus atlanticus)*	Reproduce early (2 years) and often. Found in the coastal habitats of the western Atlantic from northeastern US to Brazil. Feed on other fish, squid, and crustaceans such as shrimp, crabs, and amphipods.	70 cm (2.3 ft) 110 cm (3.6 ft)	~7 years	Steaks	
 **Albacore** *(Thunnus alalunga)*	Reproduce later (5-6 years). Widely distributed in temperate and tropical waters of all oceans, including the Mediterranean Sea. Feed mostly on deepwater squid and some fish and pelagic crustaceans.	100 cm (3.3 ft) 140 cm (4.6 ft)	~13 years	Canned white tuna and steaks	
 **Longtail** *(Thunnus tonggol)*	Grow more slowly and live longer than similar sized tuna species. Feed on a variety of fish, cephalopods, and crustaceans, particularly prawns.	70 cm (2.3 ft) 145 cm (4.8 ft)	~18 years	Marketed mainly fresh and dried salted, but also smoked, canned, and frozen.	
 **Yellowfin** *(Thunnus albacares)*	Reproduce early (1-2 years) and often. Found in the tropical and subtropical areas of the Atlantic, Indian, and Pacific Oceans. Feed on other fish, pelagic crustaceans, and squid.	150 cm (4.9 ft) 240 cm (7.9 ft)	~9 years	Canned, sushi, sashimi, steaks	
 **Bigeye** *(Thunnus obesus)*	Reproduce later (5 years). Found in the tropical and subtropical areas of the Atlantic (but not the Mediterranean), Indian, and Pacific Oceans. Primarily feed on other fish, crustaceans, and squid.	180 cm (5.9 ft) 250 cm (8.2 ft)	~16 years	Sushi, sashimi	
Southern Bluefin *(Thunnus maccoyii)*	Reproduce later (5 years). Live in the South Pacific. Feed on small fish, crustaceans, and invertebrates such as squid.	160 cm (5.2 ft) 250 cm (8.2 ft)	~40 years	Sushi, steaks	
Pacific Bluefin *(Thunnus orientalis)*	Reproduce later (5 years). Live in the North Pacific. Feed on small fish such as sardines, herring, and mackerel, and invertebrates such as squid.	200 cm (6.6 ft) 300 cm (9.8 ft)	~26 years	Sushi, sashimi, steaks	
 **Atlantic Bluefin** *(Thunnus thynnus)*	Reproduce later (5 years). Live in subtropical and temperate waters of the Atlantic Ocean and Mediterranean Sea. Feed on small fish such as sardines, herring, and mackerel, and invertebrates such as squid.	200 cm (6.6 ft) 458 cm (15 ft)	~50 years	Sushi, steaks	

*See legend on page 5.

GBMS and the Global Mercury Assessment 2018

The GBMS database is the basis for a new chapter about mercury in biota for the 2018 Global Mercury Assessment published by the Arctic Monitoring and Assessment Programme and UN Environment. For the first time, mercury concentrations are provided for major taxonomic groups (i.e., fish, sea turtles, birds, and marine mammals) at a global level. Spatial gradients of MeHg availability across the world provide a unique platform for beginning to understand regional biological mercury hotspots (those geographic areas where environmental mercury concentrations are of biological concern).

Eating Tuna - What's Safe?

Higher Concern ⟵ Lower Concern

Meal Frequency Recommendations			
1-2 meals per week (0.05–0.22 µg/g)	Skipjack (light tuna) Safe Catch® brand tests every tuna for low mercury.	Yellowfin (ahi)	Yellowfin (ahi)
1 meal per month (0.22–0.95 µg/g)	Albacore Yellowfin (ahi) (white tuna)	Bigeye Atlantic Bluefin Southern Bluefin	Albacore Longtail Atlantic Bluefin Southern Bluefin
No consumption (> 0.95 µg/g)		Pacific Bluefin Small bluefin: 1 meal/month; large bluefin:"no consumption"	Blackfin Pacific Bluefin

Data Sources: BRI's Global Biotic Mercury Synthesis (GBMS) Database; US EPA; US Food and Drug Administration

Interpreting Mercury Concentrations and Risks of Exposure

Mercury concentrations presented can be compared with the number of seafood meals that can be consumed to stay within the US EPA's health-based reference dose for methylmercury. The guidance is based on the US EPA reference dose of 1x10-4mg of Hg/kg of body weight/day, a body weight of 132 pounds (60 kg) for an adult female person, and about 6 ounces of fish (170 gm). These guidelines, with further interpretation by the Great Lakes Consortium (Great Lakes Fish Advisory Workgroup. 2007) are provided in the chart above for meal frequencies. For further reference, WHO and the EC general guidance level for fish mercury concentrations is 0.5 ppm with an "exemption" for larger, predatory fish species (e.g., some tuna species) of up to 1.0 ppm, which is similar to the US EPA "no consumption" level.

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CREDITS

Editorial: Deborah McKew; **Design/Production:** Erin Covey-Smith; **Maps:** Mark Burton; **Illustrations:** Shearon Murphy. **Photos:** Cover: Atlantic Bluefin tuna courtesy NOAA Fisheries; Yellowfin tuna by Jeff Muir, courtesy NOAA Fisheries; p. 2: Bluefin tuna harvest in Eastern Mediterranean © zaferkizilkaya-shutterstock.

Data Sources

[1]Netting Billions: A Global Valuation of Tuna REPORT May 2, 2016 PEW Charitable Trust Graphic: Top Ten Tuna Fishing Nations (p3) © The Pew Charitable Trusts. Used with permission. The views expressed herein are those of the author(s) and do not necessarily reflect the views of The Pew Charitable Trusts.
Note: 2014 tuna landings (seven species combined) based on data provided by fishing nations to regional fisheries management bodies. Source: Graeme Macfadyen, Estimate of Global Sales Values From Tuna Fisheries—Phase 3 Report (Lymington: Poseidon Aquatic Resource Management Ltd., 2016) © 2016 The Pew Charitable Trusts.

[2]Putting Bluefin Tuna Back on the Menu—by Farming Them. Nancy Bazilchuk and Anne Sliper Midling. GEMINI Research News. Online January 26, 2017.

[3]Seychelles Fishing Authority pers. com.

[4]International Seafood Sustainability Foundation, ISSF Tuna Stock Status Update, 2016: Status of the World Fisheries for Tuna (2016), http://iss-foundation.org/about-tuna/status-of-the-stocks

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