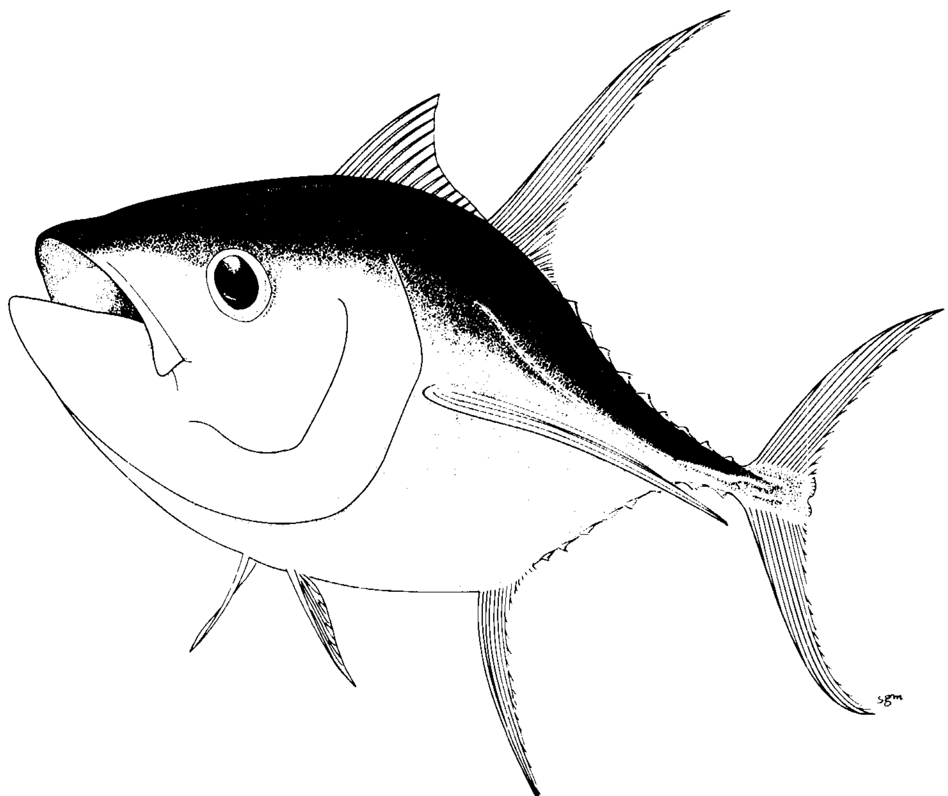
THE MANAGEMENT OF YELLOWFIN TUNA IN THE HANDLINE FISHING INDUSTRY OF HAWAII

A FISH-HANDLING HANDBOOK



December 1987

Sea Grant Advisory Report
UNIHI-SEAGRANT-AR-88-01
University of Hawaii Sea Grant College Program
Honolulu, Hawaii

Contribution No. 36
Ocean Resources Branch
Department of Business and Economic Development
State of Hawaii

This handbook was published with funds from the "Sea Grant Extension Service" project (A/AS-1) and the "Program Development" project (M/PM-2) which are sponsored by the University of Hawaii Sea Grant College Program under Institutional Grant No. NA85AA-D-SG082 from NOAA Office of Sea Grant, Department of Commerce; and from the Ocean Resources Branch, Department of Business and Economic Development, State of Hawaii. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notations that may appear hereon.

The National Sea Grant College Program is a network of institutions working together to promote the wise use, development, and conservation of the nation's coastal, marine, and Great Lakes resources. Provisions of the National Sea Grant College and Program Act of 1966 called for the creation of Sea Grant Colleges, and in October 1972, the University of Hawaii was designated one of the first five Sea Grant Colleges in the nation. Locally, Sea Grant is a unique partnership of university, government, and industry focusing on marine research, education, and advisory/extension service.

THE MANAGEMENT OF YELLOWFIN TUNA IN THE HANDLINE FISHING INDUSTRY OF HAWAII

A FISH-HANDLING HANDBOOK

Robert M. Nakamura
Jason S. Akamine
David E. Coleman
Susan N. Takashima

Library of Congress Cataloging in Publication Data

Nakamura, Robert M.

The Management of Yellowfin Tuna in the Handline Fishing Industry of Hawaii: A Fish-Handling Handbook

Sea Grant Advisory Report, UNIHI-SEAGRANT-AR-88-01
State of Hawaii, Ocean Resources Branch Contribution No. 36

1. Tuna Fisheries 2. Yellowfin Tuna 3. Fisheries—Production Standards

I. Akamine, Jason S. II. Coleman, David E. III. Takashima, Susan N. IV. Title

SH 351.T8 639.2758

About the Authors

Robert M. Nakamura is a researcher and **Jason S. Akamine** is a junior researcher, Department of Animal Sciences, 1800 East-West Road, University of Hawaii at Manoa, Honolulu, HI 96822. **David E. Coleman** and **Susan N. Takashima** were a junior researcher and a student helper, respectively, in the Department of Animal Sciences at the time this handbook was written.

The views expressed in this report do not necessarily reflect those of the University of Hawaii or the University of Hawaii Sea Grant College Program. Any errors are the sole responsibility of the authors. Any commercial product or tradename mentioned herein is not to be construed as an endorsement.

The authors and the publisher specifically disclaim any liability, loss, or risk incurred as a result of the use and application, either directly or indirectly, of any advice and information presented in this publication.

ABSTRACT

In Hawaii, yellowfin tuna caught by handlining are susceptible to a condition called "burnt tuna syndrome." The flesh of affected tuna appears pale and watery and has a sour-to-bitter taste and chewy texture. This condition decreases the quality — and hence the value — of the fish, resulting in severe economic losses to the handline fishing industry. The losses for 1986 were estimated at more than $1.4 million. Research has shown that this and other conditions of poor-quality fish result from poor management and poor handling by fishermen and fish processors.

This handbook includes some information on the burnt tuna syndrome, summaries of the authors' research findings and observations, and general guidelines and step-by-step procedures for proper handling and preparation of fish for efficient cooling — including rapid landing, stunning, killing, bleeding, gilling, gutting, beheading, and washing. Efficient cooling requires submersion of fish in an ice-brine mixture to reduce the core temperature to 0°C (32°F) within 24 to 48 hours after landing. Thereafter, fish must be stored and shipped imbedded in crushed ice and maintained on ice until sold. These procedures are essential for reducing losses and improving the quality of large tuna for sale in local and export markets. Furthermore, the guidelines and procedures may be applied to maintain good quality in other fish caught using other methods.

ACKNOWLEDGMENTS

Thanks are due to the following people: fishermen and fish processors in Hawaii who cooperated with our efforts; Darrel Kuamoo, Miles Kaichi, Hitoshi Ariga, Robert Bourke, Mark Suiso, and Dr. Robert Nishimoto for their contributions; Susan G. Monden, with whom we have worked to capture the art of fish processing in illustrations, for her artistic design talents; and staff of the Sea Grant communications office for their patience and help. Special thanks are given to Karen Y. Tanoue whose support and efforts were essential for the completion of this handbook. Thanks are also due to the United Fishing Agency in Honolulu, the Suisan Company in Hilo, and Roy and Barbara Koi of Naalehu for their cooperation.

Research funding was provided by the following organizations: Department of Research and Development, County of Hawaii; Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii; Ocean Resources Branch, Department of Business and Economic Development, State of Hawaii; National Marine Fisheries Service, National Oceanic and Atmospheric Administration; and University of Hawaii Sea Grant College Program.

TABLE OF CONTENTS

INTRODUCTION 1

BURNT TUNA SYNDROME 2
- Causes 2
- Detection 3

RESEARCH RESULTS 4

HANDLING PROCEDURES 5
- Preparing the Deck Prior to Hookup 5
- Landing the Fish 6
  - Run-fight time 6
  - Gaffing 6
  - Stunning and killing 7
- Cleaning the Fish 10
  - Bleeding 10
  - Gutting and gilling 13
- Chilling and Storing the Fish 24
  - Ice 24
  - Ice-seawater mixture 25
  - Ice-brine solution 25
  - Placement in chill boxes 25
  - Water circulation 25
  - Refrigerated chill boxes 26
  - Storage 26
- Transporting and Shipping Fish 26
- Handling Fish 27

SUMMARY OF FISH-HANDLING PROCEDURES 28

APPENDIX 29

REFERENCES 31

INTRODUCTION

The handline fishing industry in Hawaii mainly supplied fish to local markets until the late 1970s when the industry began increasing its exports to the U.S. mainland. Today it is a sizable industry, competing with fish industries from all over the world. To be competitive, however, it must be able to provide good-quality fish.

The principal target of the handline fishing industry in Hawaii is the yellowfin tuna *(Thunnus albacares)*. Unfortunately, large tuna caught by handlining are susceptible to a condition called "burnt tuna," or *yake-niku* as it is called by the Japanese. The flesh of tuna affected by the "burnt tuna syndrome" (BTS) appears pale and watery and has a sour-to-bitter taste and chewy texture. Because this condition makes the tuna less desirable for consumption as *sashimi*, it significantly decreases the fish's value. The Japanese conducted much of the early research on this condition (Konagaya and Konagaya, 1979).

Studies conducted in the 1980s at the Honolulu fish auction revealed that even mildly burnt tuna sold for about $.50 per pound less than unburnt tuna. Severely burnt fish sold for about $1 per pound less or could not be sold at all when good-quality fish were plentiful. In 1983, losses due to poor-quality large tuna were estimated at more than $1 million (S. Miller and R.M. Nakamura, unpublished data). With increased fish landings in 1986, the losses were estimated at more than $1.4 million.

Since its beginning in the Hilo area in the 1920s, the *ika-shibi* (or night handline) fishery has been plagued by the burnt tuna syndrome (Yuen, 1979). Until recently, few people in the industry thought that any measures could be taken to prevent or control this condition. Studies by the Japanese — and more recently by University of Hawaii scientists — proved that the burnt tuna condition can be reduced and nearly eliminated by using careful handling and efficient cooling techniques. It was found that these techniques can also improve the quality of the fish, resulting in longer shelf-life. This is important in marketing fish, particularly in export markets.

Thus, if Hawaii's handline fishing industry is to be competitive in the export market, it must develop a reputation for quality. Its standards for good-quality fish must be at least as high as — and preferably higher than — those of other exporting localities.

The intent of this handbook is to assist fishermen and fish processors in maintaining the quality of large tuna. Included are some information on the burnt tuna syndrome, summaries of the authors' research findings and observations, and general guidelines and step-by-step procedures for processing and handling large yellowfin tuna for local and export markets. By closely following the step-by-step procedures provided, an immediate improvement in quality and market value of the fish can be achieved. Furthermore, although mainly concerned with handline-caught yellowfin tuna, the guidelines and procedures presented in this handbook may be applied to maintain good quality in other fish caught using other methods.

This handbook was compiled from research findings and observations made by the authors at various fish auctions and on board commercial ika-shibi fishing vessels. It also includes research, observations, and recommendations by Japanese workers, as well as information and recommendations from other fish-handling handbooks.

BURNT TUNA SYNDROME

Mild forms of burnt tuna involve only a small, pale strip of flesh along the most central portion of the fish, whereas severe cases may involve the entire fish. Previous research showed that this condition is a degenerative phenomenon which occurs only after the fish is dead (Cramer et al., 1981). Auction studies showed that the highest incidences of BTS (about 50 percent) occur in the sport fishing catch (Coleman et al., 1985). Fewer incidences (23 percent) occur in the ika-shibi catch, and even fewer (less than 5 percent) in the catch landed using the longline or flagline method. BTS is also a problem with tuna caught in purse seines.

Causes

Elevated body temperature, lactic acid production, and proteolytic enzyme activity — all cause BTS, the result of which is poor-quality fish. Inefficient cooling immediately after boating the fish is an important factor in the occurrence of BTS.

Tuna are capable of attaining body temperatures around 10°C (18°F) above seawater temperature because of its unique counter-current circulatory system in which cooler blood entering the muscle is warmed by the close proximity to naturally heated blood leaving the muscle (Carey, 1973). Blood passing through the gills is the principal means of cooling the fish (Brill et al., 1978). This cooling system ceases to function when the fish is removed from water, resulting in rapid deterioration of the muscle owing to elevated body temperatures.

Fish get their energy by breaking down carbohydrates. This process is called glycolysis. During intense and prolonged fighting, the fish's metabolism changes from aerobic (with oxygen) to anaerobic (without oxygen) glycolysis in order to obtain energy from stored sources. When the fish is taken out of water, the change to anerobic glycolysis also occurs. The by-product of anaerobic glycolysis is lactic acid, which lowers the pH of the fish and imparts the acidity that causes BTS.

Proteolytic enzymes break down, or digest, the fish flesh, making it soft and mushy. These enzymes are chemical substances, and they remain active even after the fish is dead. Proteolytic enzymes come from two sources: some are released by the fish's body; others are introduced by bacteria. It is important to note that they digest flesh faster at higher temperatures and their action almost stops at freezing temperatures. Furthermore, enzymatic activity in fish flesh is about 10 times greater than that in beef or pork (Siebert, 1958), which means that more rapid and efficient cooling is necessary to ensure prolonged shelf-life for fish than for mammals.

Detection

A fish may appear to be sufficiently cooled and the superficial layers and tail area may seem to be of good quality — but how can the quality of the deeper parts of the fish be determined? Sometimes the fish are quartered to expose the interior, but the market prefers whole fish. In Japan, and to an increasing extent on the neighbor islands, a core sample is taken using a tool similar to a cheese corer. It removes a cylindrical sample from the surface to the interior of the fish. The core is examined for freshness, fat content, color, and other characteristics. These samplings are accurate for detecting BTS only when used on fish with near-freezing core temperatures. Readings made prematurely will not account for the continuing loss of quality in fish that have not yet reached near-freezing temperatures.

RESEARCH RESULTS

The following are summaries of research results and observations from studies conducted by the authors from 1982 to 1986.

1. Recently it has become apparent that the real problem of the large-tuna industry is loss of quality resulting from slow, inefficient cooling and poor handling of the fish. Although most of the attention in the past has been on BTS, this is only one of the manifestations of quality loss in tuna. Other characteristics of poor-quality tuna are loss of color, dark-colored flesh, watery or slimy flesh, loss of flavor, changes in odor, changes in the texture of the flesh, loss of translucency of the flesh, and decreased shelf-life. The last characteristic may occur even in the absence of BTS. The decrease in shelf-life is particularly critical to fish destined for distant export markets.
2. Industry costs due to poor-quality tuna, other than costs due to BTS, are inestimable both in the local and the export markets. Competing countries have already recognized these problems and taken steps to correct them. Some countries utilize quality-control officers from Japan who reject fish at the fishermen's level, preventing poor-quality fish from reaching the export markets. However, because Hawaii has no quality-control officer, fish with BTS, shortened shelf-life, and other characteristics of poor quality often reach the mainland export markets, where they are rejected. This practice of exporting poor-quality fish may be detrimental to the large-tuna industry here; the export markets may conclude that most of the fish from Hawaii are of poor quality and thus may prefer fish from other sources.
3. Large fish are more predisposed to BTS than small fish. Although it is generally thought that BTS occurs most often in fish larger than 80 pounds, this condition has been observed in yellowfin tuna ranging from 20 to 40 pounds.
4. Female fish are more often affected with BTS than male fish. Also, female fish are affected with a higher incidence of BTS in most months of the year. The sex of the fish is often a more important factor than the size.
5. The incidence of BTS rises sharply when more than six fish are caught during a single trip. The facilities aboard

most boats cannot adequately handle more than six fish per trip.

6. Longer fight times and increased number of runs by the fish before landing increase the incidences of BTS.
7. Killing the fish by clubbing decreases the incidence of BTS when compared with shooting the fish.
8. Fish caught after 3 a.m. are more likely to be affected with BTS than fish caught earlier during overnight ika-shibi fishing trips. This observation is probably related to not having adequate time to cool the fish before removing them from the chill box when off-loading at dockside.
9. Because the deep body temperature of landed fish is the most important factor in the occurrence of BTS, the rate and extent of cooling are of primary concern. BTS-affected fish have consistently higher internal temperatures throughout the first 24 hours after landing than non-BTS-affected fish.

HANDLING PROCEDURES

The strategy involved in processing fish to maintain their quality is to utilize fast and efficient cooling methods. Combining information from the authors' own experiences in the field and recommendations from fish-handling handbooks (Taniguchi, 1977; Kramer and Paust, 1985; Ehrich, 1986; Gibson, 1981; Williams, 1986; Lassen, 1965; Rowley, 1983; Boyd et al., 1982), specific guidelines for the processing and handling of large, fresh-chilled tuna were established. The step-by-step procedures outlined below describe ways to increase the efficiency and rapidity of cooling fish.

Preparing the Deck Prior to Hookup

Good deck practices require the proper order and arrangement of equipment and processing utensils so that the fish can be handled quickly. A properly prepared deck can minimize physical damage, prevent contamination, and allow for efficient stunning, killing, bleeding, gilling, gutting, washing, and chilling by the crew. Furthermore, advance preparation can greatly aid in the processing and cooling of the catch with very little disruption of the fishing operation. Some of the recommended procedures are as follows:

- Clean and sanitize the fish box.
- Keep equipment such as gaffs, clubs, spiking tools, knives, and fishing gear near the area where they will be used.
- Chip ice blocks into small pieces or have bags of crushed ice ready for immediate chilling of fish.
- Clear the way for easy access to the fish box.

Landing the Fish

Run-fight time

More runs after hookup mean longer fight time and an increased chance of BTS occurrence. To reduce this possibility, the number of runs should be minimized and tuna should be landed as rapidly as possible — ideally within 6 minutes of hookup.

Gaffing

The best place to gaff a fish is through the lower jaw (Figure 1) because it is strong enough to support the fish when lifted. Also, a gaff through the jaw makes it easy to position the fish for stunning. Gaffs should not be made through the body or the heart. A gaff through the body reduces the value of the fish, and an accidental gaff through the heart ruins the chances for proper bleeding.

Figure 1. Gaff the fish through the lower jaw.

Stunning and killing

Longer struggling time results in increased body temperature, bruising, scale loss, and muscular contractions. Fish should be stunned and killed as quickly as possible. The best place to club a fish is on the soft spot. The soft spot, which is whitish in color, is located on the mid-dorsal line just above the eyes (Taniguchi, 1977). The brain is located slightly behind the soft spot.

Stunning

Fish should be stunned by clubbing immediately after gaffing or as soon as they are brought on board. Clubbing can be accomplished with a bat, mallet, or lead-filled steel pipe (Figure 2).

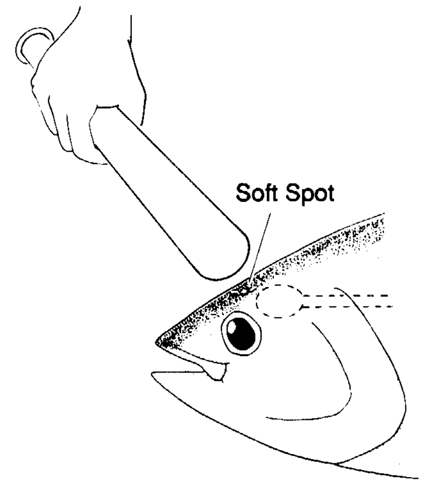


Figure 2. Stun the fish by clubbing the soft spot between the eyes.

Killing

Sometimes stunning only temporarily renders the fish unconscious. Fish that appear to be dead can recover and start to thrash in the fish box. To prevent this, the fish should be killed immediately after stunning by destroying the brain. Three techniques are described below. When properly executed, the fish will shudder once, become limp, and die.

The first technique involves the use of a sharp probe such as an ice pick or a screwdriver. These are simple tools which can be used to quickly and easily kill the fish (Figure 3).

Step 1 **Place a sharp probe on either side of the soft spot.**

Step 2 **Pierce the skin, and then push the probe down until the skull is reached.**

Step 3 **Apply downward pressure on the probe, and then slide it backward in the direction of the tail until you reach a thin cartilaginous plate at the base of the ridge. The plate will collapse, and the probe will sink about 1 inch deeper into the brain.**

Step 4 **Move the probe back and forth to destroy the brain.**

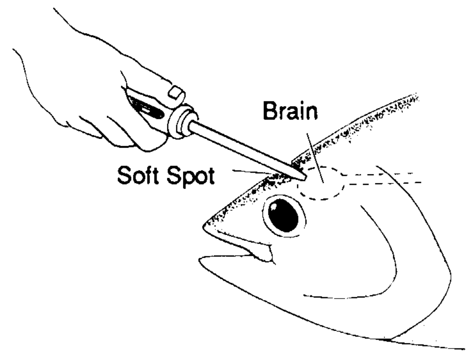


Figure 3. Destroy the brain on either side of the soft spot using an ice pick or screwdriver.

Another killing technique involves the use of the Taniguchi tool (Figure 4). Developed in Japan by Dr. H. Taniguchi (1977) and used mainly on longline fishing vessels, this tool consists of a short metal tube and a rod. A welding rod or flexible plastic rod may also be used.

Step 1 Bore a hole into the fish's brain at the soft spot.

Step 2 Force the rod through the tube, into the brain, and down the hollow core of the spinal canal to destroy the spinal cord.

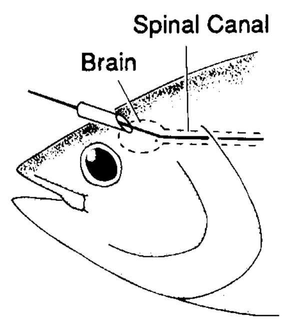


Figure 4. Insert the metal tube through the brain, followed by the rod into the spinal canal to destroy the spinal cord.

A third technique used to kill fish involves the use of a hacksaw and rod (Figure 5). A sharp knife may be used in place of the hacksaw.

Step 1 **Using a hacksaw, cut a wedge from the area over the soft spot to the base of the eyes.**

Step 2 **Remove the wedge to expose the brain.**

Step 3 **Insert a rod through the brain and into the spinal canal to destroy the spinal cord.**

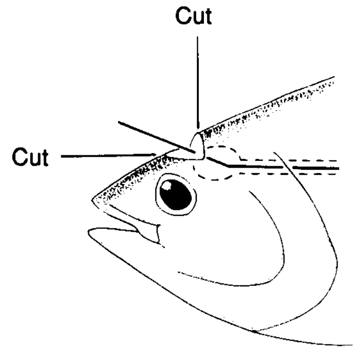


Figure 5. Cut a wedge over the soft spot to expose the brain, and then pass a rod through the brain into the spinal canal.

Cleaning the Fish

Bleeding

Fish should be bled for 5 minutes immediately after killing. Removal of the "hot" blood allows the fish to cool more rapidly. When bleeding, it is important not to damage the heart. The heart, which continues to function even after the brain is destroyed, must be kept intact in order for it to pump the blood out of the fish. Three methods for proper bleeding are given below.

Pectoral cut

To make the pectoral cut, a short, narrow knife roughly 2 inches long by 1/2 inch wide should be used since the blood vessel (subcutaneous artery) lies no more than 1 inch below the skin surface of the fish. A sharpened oyster shucker or any other similar-sized knife is ideal. The knife should be kept extra clean to prevent bacteria — which may contribute to accelerated spoilage — from being introduced into the fish.

Step 1 **Locate a spot the width of three fingers behind the base of the pectoral fin and about 1/4 inch below the lateral median line which extends along the side of the fish (Figure 6).**

Step 2 To sever the blood vessel, make a 1 to 2-inch cut, 1 inch deep, from the spot toward the base of the pectoral fin.

Step 3 Make this cut on both sides of the fish.

Step 4 To drain the blood from the fish, position it head down, on an incline. Shoot water on the fish to prevent blood clotting.

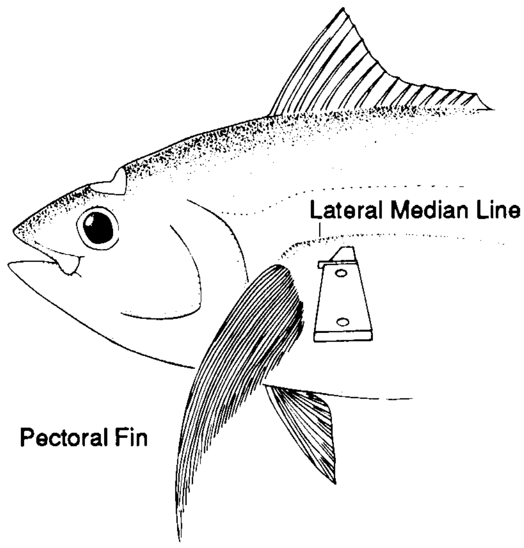


Figure 6. Bleed fish by cutting behind the pectoral fin.

Gill cut

Step 1 Position the fish so that it is lying on its side.

Step 2 Pull open one side of the gill cover, and then insert a knife behind the gills through the membrane (Figure 7).

Step 3 Cut upward toward the spine to sever the blood vessels, being careful not to stab the heart.

Step 4 Make this cut on both sides of the fish.

Step 5 To drain the blood from the fish, position it head down, on an incline. Shoot water on the fish to prevent blood clotting.

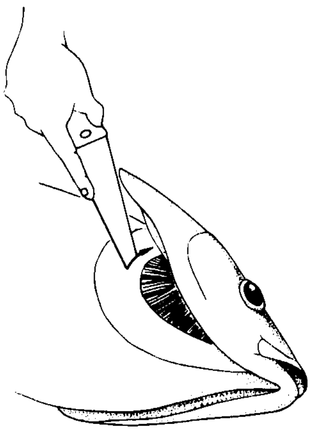


Figure 7. Bleed fish by cutting blood vessels at top of gills.

Tail cut

Step 1 Cut the blood vessel vertically between the third and fourth dorsal finlet (see appendix) from the tail (Figure 8).

Step 2 Make cuts on both sides of the fish, or remove the tail completely.

Step 3 Drain the blood from the fish. Shoot water on the fish to prevent blood clotting.

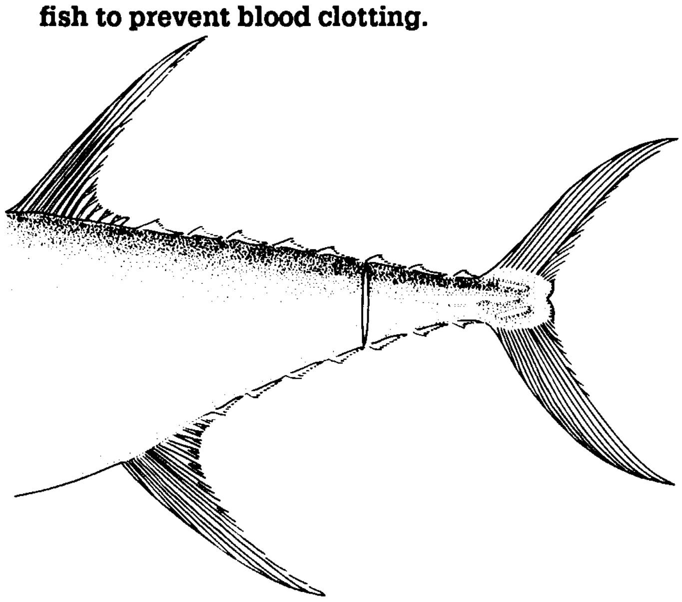


Figure 8. Bleed fish by cutting tail.

Gutting and gilling

Removing the internal organs and gills is another way to cool the fish faster to prevent spoilage and bacterial growth which can cause BTS. Also, a gutted, gilled fish can be processed faster and handled less at the market. Female and very large fish should be handled more quickly — but carefully — since they are prone to a greater incidence of BTS. Although tuna smaller than 80 pounds rarely develop BTS, those weighing as little as 5 pounds have been observed with this condition.

The sex of the fish can be determined by the presence of testicles or ovaries. During the spawning season — from May to October — the male testicles are smooth, elongated, and noticeably white in appearance; the female ovaries are elongated, rough in texture, and yellow to orange in color, and their surface is lined by prominent veins.

Fish can be gutted and gilled with the head on or off. Both approaches are given below.

Head-on approach

With the head-on approach, the head is left intact and the guts and gills are removed through the gill opening. The following are step-by-step instructions.

Step 1 Make a straight, 4-inch slit in the belly, cutting toward the anus (Figure 9).

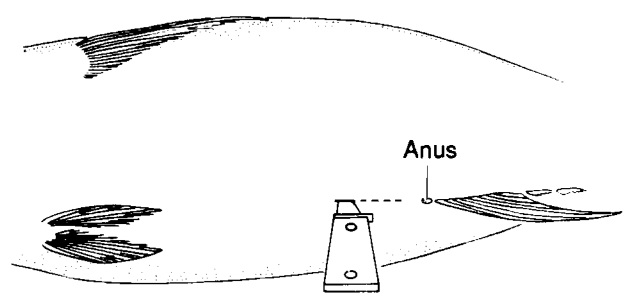


Figure 9. Insert knife 4 inches in front of the anus, and then cut toward it.

Step 2 Reach into the cavity and pull out the intestine attached to the body wall. Cut the intestine near the anus (Figure 10).

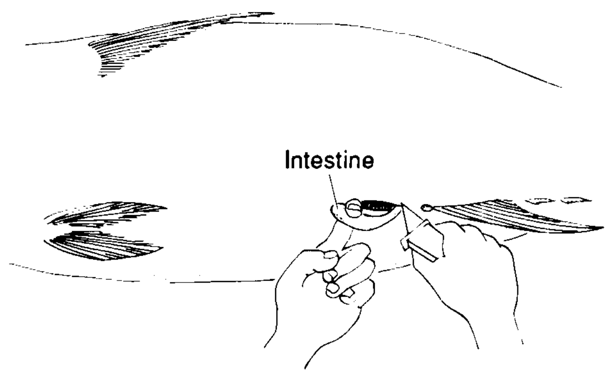


Figure 10. Cut the intestine near the anus.

Step 3 Pull one gill cover away from the body. Then insert a knife at the top of the gill cover and slide it toward the eye. Make this cut on both sides of the fish (Figure 11).

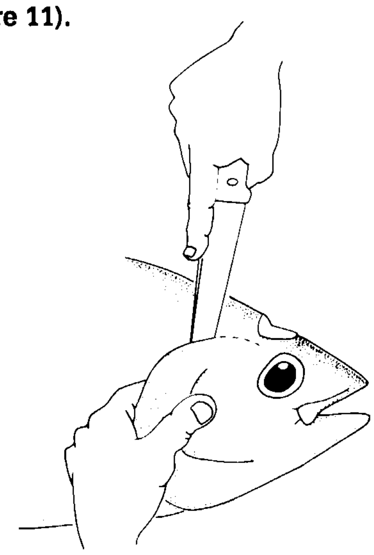


Figure 11. Insert knife at the top of the gill cover and slide it toward the eye.

Step 4 **Pull the gill cover back, reach inside the cavity with a knife, and then cut the main muscle attaching the gill cover to the head. Make this cut on both sides of the fish to allow easier access to the gills, which need to be removed (Figure 12).**

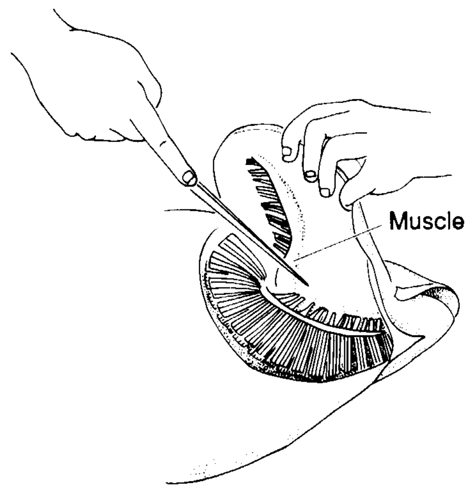


Figure 12. Cut the main muscle attaching the gill cover to the head.

Step 5 **Cut the lower end of the gill-to-head attachment and not the entire connection of the lower body to the underside of the mouth (Figure 13).**

If you cut the entire connection, unequal pressure exerted by muscle stiffening will lower the quality of the fish in two ways. First, it will cause the head to lift up and bend backward, distorting the shape and appearance of the fish. Second, this unequal pressure will cause tearing and gaping of fillets.

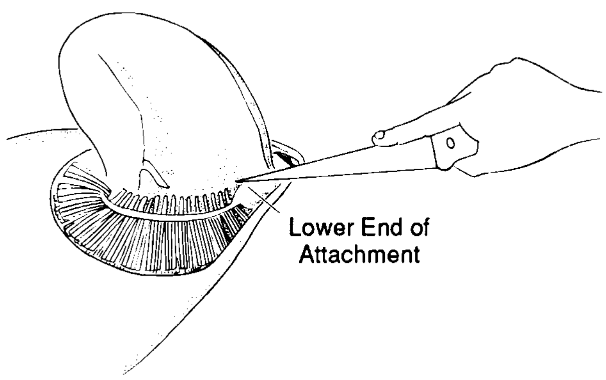


Figure 13. Cut lower end of gill-to-head attachment.

Step 6 Pull one gill cover away from the body, and then cut through the membrane behind the gills. Extend the cut through the kidneys as far back and as close to the backbone as possible. Bring the cut down each side of the gill openings. Make this cut on both sides of the fish (Figure 14).

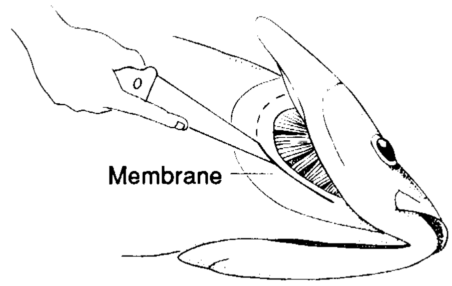


Figure 14. Cut through the membrane behind the gills.

Step 7 Pull one gill cover away from the body. Insert a knife under the gills, close to the spinal column, and cut the upper end of the gill-to-head attachment. Cut on both sides of the fish, and then free gills from the head (Figure 15).

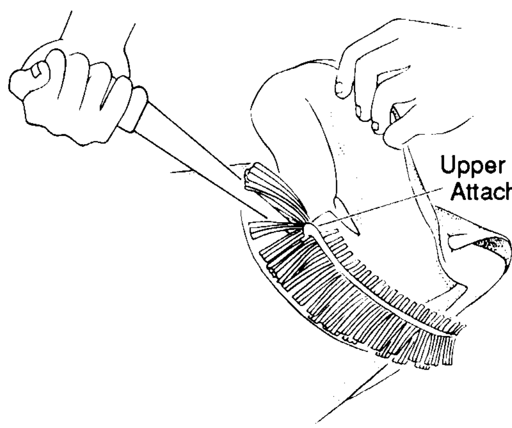


Figure 15. Cut upper end of gill-to-head attachment.

Step 8 Pull open gill cover, and then grab the lower end of the gills. Pull and remove the gills and guts. Remove any remaining attachments (Figure 16).

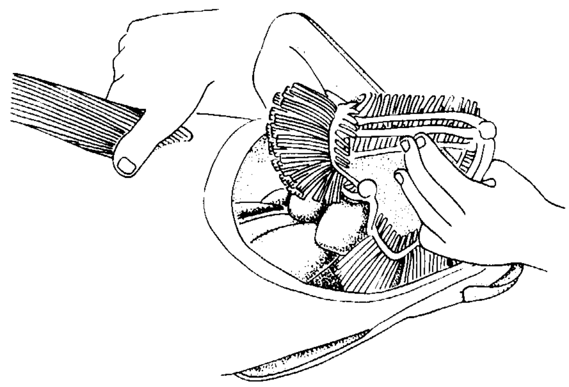


Figure 16. Remove gills and guts and any remaining attachments.

Step 9 **Remove the gonads from the cavity by sliding your hand under them and tearing the membranes anchoring them to the stomach wall.**

Step 10 **Pop the air bladder.**

Step 11 **Remove as much of the kidney and coagulated blood as possible from the backbone. Scrub the area with a stiff wire or nylon brush until spine becomes white (Figure 17).**

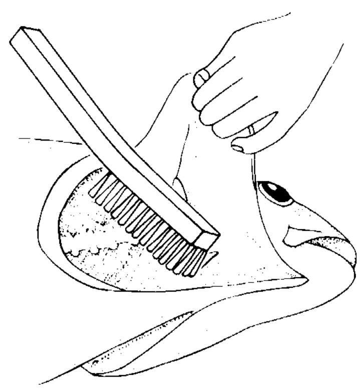


Figure 17. Scrub spine through gill openings to remove the kidney and coagulated blood.

Step 12 **Remove as much loose skin and hanging attachments as possible from the bone within the gill openings.**

Step 13 **Remove membranes from inside gill cover (Figure 18).**

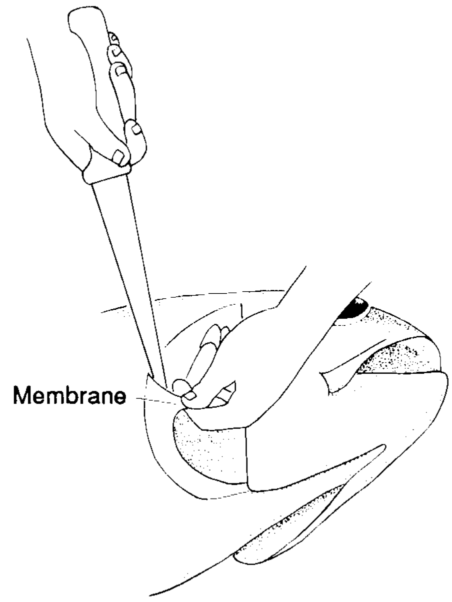


Figure 18. Trim the membranes lining the gill collar.

Step 14 Rinse fish with chilled water and wash away slime from the outside of the skin.

Step 15 Remove all fins, and even the tail, if desired (Figures 19 and 20).

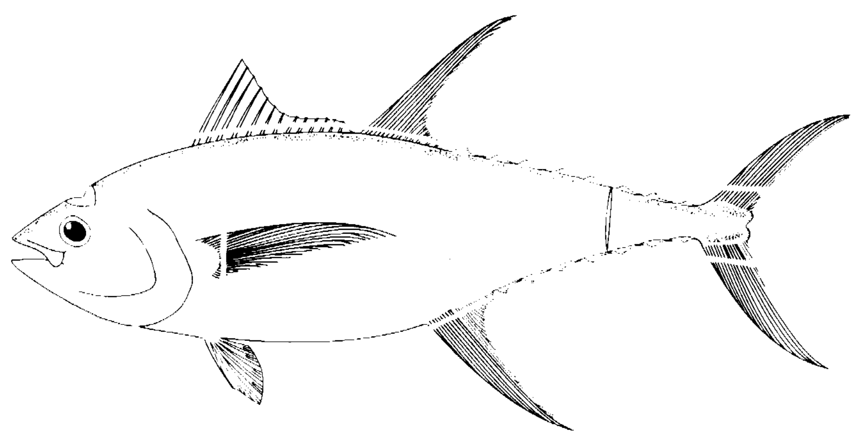


Figure 19. Remove all fins.

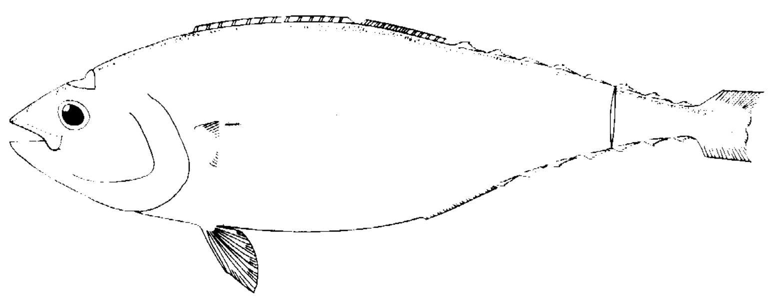


Figure 20. Gilled, gutted fish with head on and fins removed.

Step 16 Optional. For easier processing, cut off a portion of the gill cover for better access to the gills and guts. Either use a saw or bend the gill plate back until it snaps in half, and then cut along the crease with a knife (Figure 21).

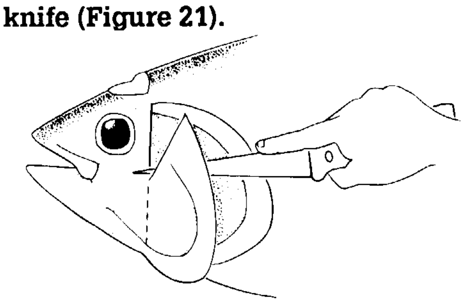


Figure 21. Saw off the gill cover or fold it back and cut along crease.

Head-off approach

With the head-off approach, a part or all of the head is sawed off and the gills and guts are removed with the head. The procedure is as follows.

Step 1 Remove the head by sawing straight down behind the eyes (Figure 22).

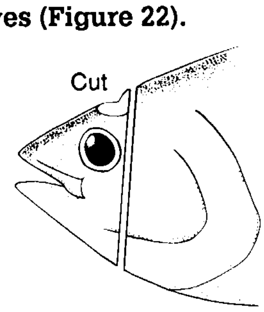


Figure 22. Saw straight down behind the eyes to remove the head.

Step 2 **Alternatively, insert the saw behind the gill cover and saw at an angle toward the snout. Make this tapered cut on both sides of the fish (Figure 23).**

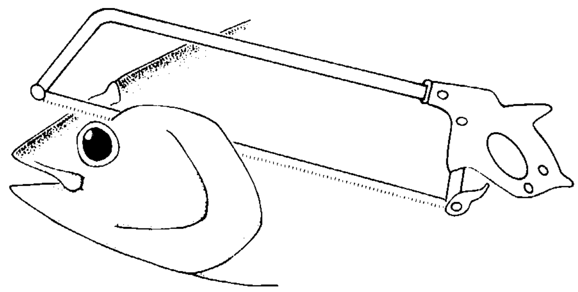


Figure 23. Saw toward snout from behind the gill cover on both sides of fish to achieve a tapered cut.

Step 3 **For gutting and gilling instructions, follow steps 1, 2, and 6 through 13 in the head-on approach section.**

Step 4 **Rinse fish with chilled water and wash away slime from the outside of the skin.**

Step 5 **Remove all fins, and even the tail, if desired (Figure 24).**

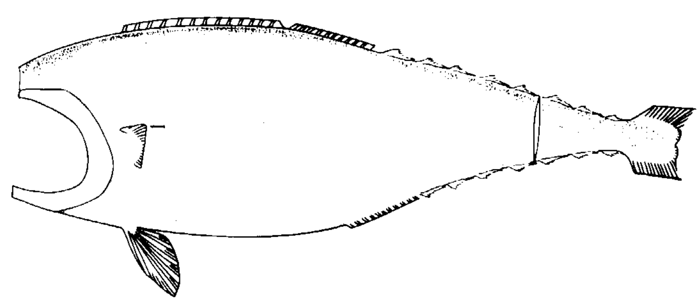


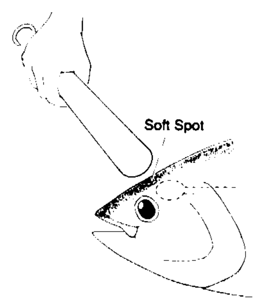
Figure 24. Gilled, gutted fish with head and fins removed.

ON BOARD HANDLING OF FISH:
Head-On Approach

1

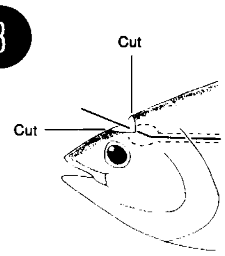
Gaff the fish through the lower jaw.

2



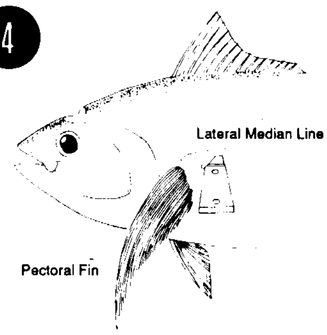
Stun the fish by clubbing the soft spot between the eyes.

3



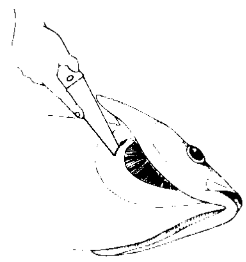
Cut a wedge over the soft spot to expose the brain, and then pass a rod through the brain into the spinal canal.

4



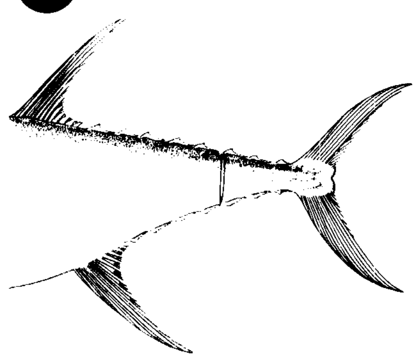
Bleed fish by cutting behind the pectoral fin.

5



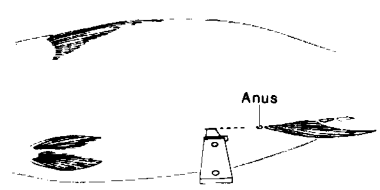
Bleed fish by cutting blood vessels at top of gills.

6



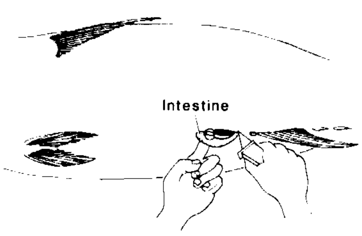
Bleed fish by cutting tail.

7



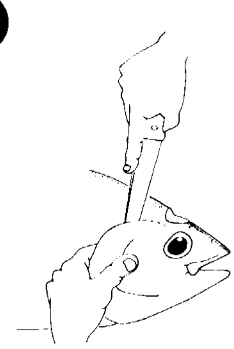
Insert knife 4" in front of the anus, and then cut toward it.

8



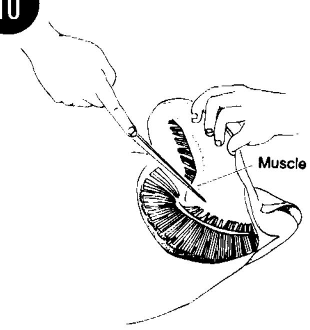
Cut the intestine near the anus.

9



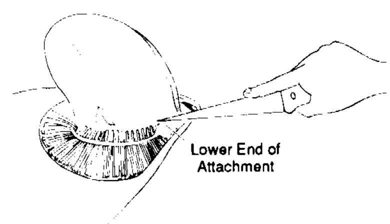
Insert knife at the top of the gill cover and slide it toward the eye.

10



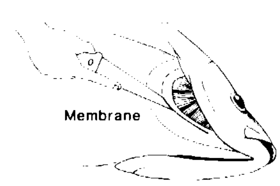
Cut the main muscle attaching the gill cover to the head.

11



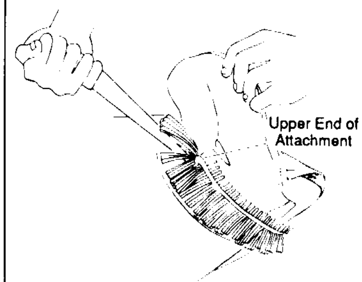
Cut lower end of gill-to-head attachment.

12



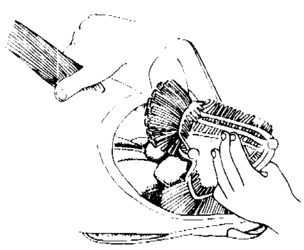
Cut through the membrane behind the gills.

13



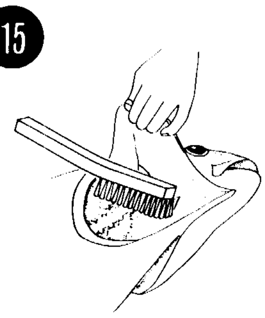
Cut upper end of gill-to-head attachment.

14



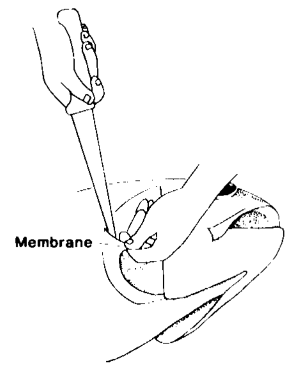
Remove gills and guts and any remaining attachments.

15



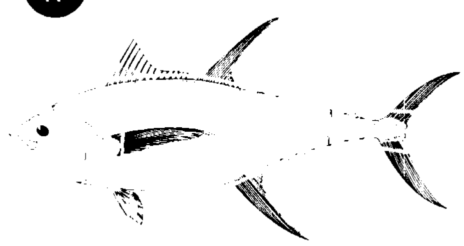
Scrub spine through gill openings to remove the kidney.

16



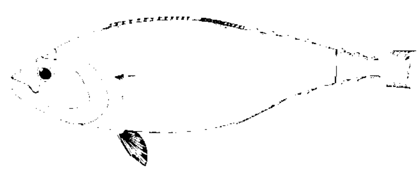
Trim the membranes lining the gill collar.

17



Remove all fins.

18



Gilled, gutted fish with head on and fins removed.

Chilling and Storing the Fish

The internal body temperature of yellowfin tuna, when first landed, may be as high as 32°C (89.6°F) — depending on the degree of fighting and the length of time between hooking and landing the fish. At the time of landing the fish is of good quality; BTS does not occur until about 3 hours later (Nakamura et al., 1977). Deterioration of fish quality begins after landing and is due to inadequate cooling and/or slow rate of cooling. The procedures given up to this point are for killing the fish rapidly to prevent bruising and further rise in body temperature, for removing "hot" blood and guts from the fish, and for preparing the fish for efficient cooling. These procedures, which should be completed within 5 to 15 minutes after landing the fish, must be followed promptly by cooling procedures. Japanese researchers believe that internal body temperatures of fish must be reduced to 26°C (79°F) within 1 hour after landing to prevent the occurrence of BTS (Gibson, 1981).

It is further believed that fish body temperatures must be reduced to 0°C (32°F) within 24 to 48 hours after landing. Since fishermen usually deliver their fish in about 6 to 8 hours after landing, it is important that the rapid cooling procedures started on their boats be continued by the wholesalers and shippers.

Cooling large fish down to 0°C is a two-stage process. In the first stage, which involves the first 12 to 24 hours of cooling, an ice-seawater mixture is used to rapidly decrease body temperature. This mixture is colder than freezing temperatures because of the salt in seawater. Smaller fish may be cooled to freezing temperatures within this period or earlier. Fish handlers should be aware that a lowering of fish quality in the form of dark-colored flesh may occur if the cooled fish become partially frozen. Fish handlers should also be aware that, after 24 hours of cooling, salt will begin to leach into tissues and the cornea of both eyes, and exposed flesh will become bleached (Rowley, 1983).

In the second stage, beginning at 12 to 24 hours of cooling, the water is drained and more crushed ice added until internal body temperatures are down to 0°C. This usually occurs after 24 to 48 hours of cooling for large fish (Boyd et al., 1982).

The following procedures are provided for efficient chilling and storing of fish to maintain their quality.

Ice

A ratio of 2 pounds of ice to 1 pound of fish is required to cool fish properly. It is probably best to take some of both crushed ice and block ice. Crushed ice can cool water faster and is easier to spread over fish. It is also used to make slushy mixtures of ice and water for rapid lowering of water temperature. To maintain the water temperature, chipped block ice is added to the mixture. Chipping block ice into smaller pieces should be done ahead of time because this activity takes up valuable time when fish are biting. Large pieces of ice may cause bruising if they are trapped under the fish.

Ice-seawater mixture

The ice-seawater mixture is made up of 1 part seawater to 2 parts ice. Less water should be used for more slushy mixtures (Williams, 1986). The mixture should completely cover the fish. More seawater should not be added since the ice will melt; more ice can be added as needed to ensure excess ice in the mixture.

Ice-brine solution

Wholesalers must take over first-stage cooling process upon delivery of fish to them. This is accomplished by placing fish in an ice-brine solution. To make the solution, salt must be added to freshwater at a ratio of about 60 pounds of salt to an estimated 1 ton of fish (Lassen, 1965).

Placement in chill boxes

Fish should be placed in chill boxes, head-to-tail, with their belly-up or placed with their best appearing side up. Large and female tuna, both of which are more predisposed to BTS, should be handled with greater care and speed and should have priority in chill boxes. The belly cavities of all fish — large and small, male and female — should be filled with crushed ice.

Water circulation

Ice floats in water, allowing for temperature stratification in the chill boxes. The water temperature will be near 0°C at the top and 10°C (50°F) near the bottom. Fishermen must turn the fish constantly for uniform chilling. Even the rocking of boats is not sufficient to obtain a uniform temperature throughout the chill box. It is highly recommended that water circulation be achieved by running a bilge pump or by bubbling air with an air compressor. Likewise, wholesalers must agitate the ice-brine solution; good results have been obtained using air compressors.

Refrigerated chill boxes

The use of refrigerated chill boxes by some fishermen and wholesalers has increased the efficiency of cooling fish. However, chipped ice must still be used since most refrigerated boxes cannot keep water temperatures down when large fish are placed in them.

If after 12 to 24 hours of cooling the internal temperatures of large fish are still above 0°C, the cooling process must be continued with ice alone. The water in chill boxes should be drained and fish covered with more ice until internal body temperatures reach 0°C.

It is highly recommended that long-probed thermometers, similar to meat thermometers, be used to monitor internal temperatures of fish. The decision to remove fish from chill boxes should be based only on sufficient hours in the box or internal body temperatures taken with thermometers.

Storage

When internal temperatures of fish reach 0°C, maintenance of fish at this temperature can best be achieved by placing them in a plastic bag and continuing to store them covered with ice. This is best achieved by storage in walk-in refrigerators. The temperature of walk-in refrigerators is often warmer than 0°C — and often over 10°C (50°F) — depending upon the temperature setting and frequency of in-and-out traffic. Wholesalers and retailers are often guilty of abusing fish by improper storage. Large yellowfin tuna that have been properly prepared, efficiently cooled, and kept constantly on ice may be kept in good condition and quality for 3 weeks or longer.

Transporting and Shipping Fish

Fish with internal body temperatures above 0°C should be transported without delay from the boat to the wholesaler and/or shipper. Fish should be transported with plenty of ice in covered, insulated containers or in refrigerated trucks. The containers should be large enough to avoid overstacking fish. Fish must be placed in an ice-brine solution so that first-stage cooling can continue. Proper precautionary measures should be taken to prevent abuses to fish during their transport from the boat to the wholesaler.

Fish should never be shipped to interisland or mainland destinations until their core temperatures are 0°C. Properly chilled fish at 0°C can withstand short periods of shipping without ice without sustaining severe damage. If possible, fish should be shipped on ice or at least with frozen ice packs in insulated or foam-lined boxes. Proper precautionary measures should be taken to avoid bruising or damaging the fish during transit.

Handling Fish

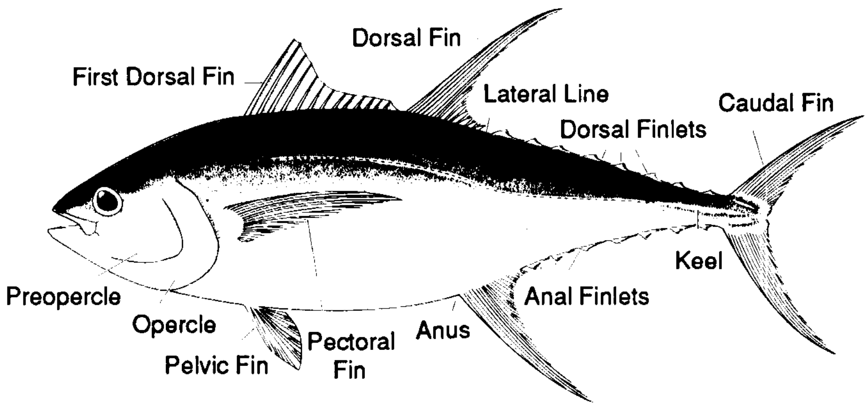
Fish should be handled gently at all times. They should never be dropped or dragged. Neither should they be bent, especially when stiff; gaping of the flesh will occur. When off-loading fish from boats or trucks, either two persons are required or winches, pulleys, or a forklift can be used. Cotton gloves are often used to avoid transferring oil from the hands to the fish. Abused fish or fish with bruises, soft areas, or missing scales often are sold at lower prices.

Fish should not be removed from ice until their core temperatures are reduced to 0°C. Fish with temperatures above 0°C should not be left on the auction floor or cutting table for any length of time — or at all. It is recommended that all manipulations of fish, such as cutting and packing, be done in refrigerated areas.

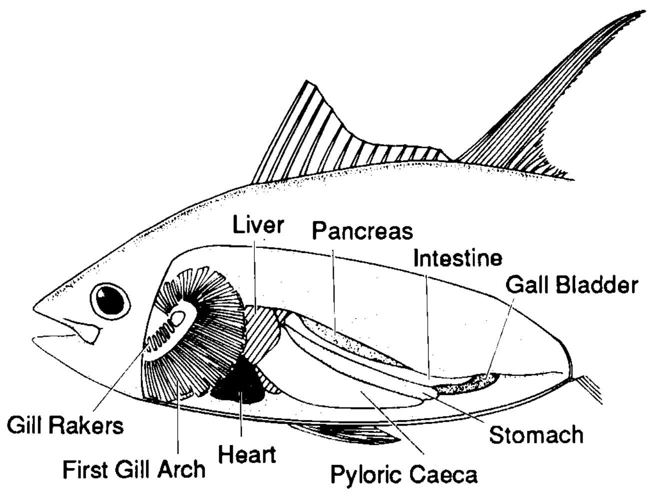
SUMMARY OF FISH-HANDLING PROCEDURES

- Bring fish on board as fast as you can.
- Gaff through the lower jaw.
- Stop the fish from struggling by clubbing.
- Work quickly, and handle the fish gently at all times.
- Kill the fish with a spike in the brain as soon as it is landed.
- Bleed the fish immediately after killing.
- Gut and gill the fish following bleeding.
- Clean and rinse the fish following gutting and gilling.
- Start chilling as soon as possible.
- Chill female and larger fish first.
- Continue chilling the fish in an ice-seawater mixture while transporting to the wholesaler.
- Continue chilling the fish as long as it is in your possession.
- Market only those fish that have been cooled to a core temperature of nearly 0°C (32°F).

APPENDIX



External Anatomy of Yellowfin Tuna



Internal Organs of Yellowfin Tuna

REFERENCES

Brill, R.W., D.L. Guernsey, and E.D. Stevens. 1978. Body surfaces and gill heat losses in restrained skipjack tunas. In *Physiological Ecology of Tunas*, ed. G.D. Sharp and D.E. Digori, pp. 261-267. New York: Academic Press.

Boyd, N.S., N.D. Wilson, and B.I. Hall. 1982. The chilling of southern bluefin tuna. In *Le Froid et le Commerce Mondial des Denrees Perissables, Hamilton, New Zealand*, pp. 153-158. Commissions CZ-D1-D2-D3, Hamilton, New Zealand. International Institute of Refrigeration, Paris, France.

Carey, F.G. 1973. Fishes with warm bodies. *Scientific American* 228: 36-44.

Coleman, D.E., R.M. Nakamura, R.E. Bourke, J.S. Akamine, S.N. Takashima, E.M.L. Chang, and W.Y. Toma. 1985. A study of "burnt tuna syndrome" in Hawaii. Department of Animal Sciences, University of Hawaii at Manoa, Honolulu. Photocopy.

Cramer, J.L., R.M. Nakamura, A.E. Dizon, and W.N. Ikehara. 1981. Burnt tuna: Conditions leading to rapid deterioration in the quality of raw tuna. *Marine Fisheries Review* 43(6):12-16.

Ehrich, N.F. 1986. *The Seafood Quality Handbook.* First Edition. Queensland Fishing Industry Training Committee.

Gibson, D.J.M. 1981. *A Handbook on Processing Southern Bluefin Tuna for the Fresh Chilled Sashimi Market in Japan.* Ministry of Agriculture and Fishery, Wellington, New Zealand. pp. 1-34.

Konagaya, S., and T. Konagaya. 1979. Acid denaturation of myofibrillar protein as the main cause of formation of "yake-niku", a spontaneously done meat, in red meat fish. *Bulletin of the Japanese Society of Scientific Fisheries* 45(2):245.

Kramer, D.E., and B.C. Paust. 1985. *Care of Halibut Aboard the Fishing Vessel.* Marine Advisory Bulletin, No. 18. Alaska Sea Grant College Program, University of Alaska. pp. 1-30.

Lassen, S. 1965. Tuna canning and preservation of the raw material through brine refrigeration. In *Fish as Food*, Vol. 4, Processing: Part 2. Academic Press.

Nakamura, K., M. Fujii, and S. Ishikawa. 1977. Experiments on the prevention of "burning" of tunas — I. An explanation of causes of occurrence. *Bulletin of Tokai Regional Fisheries Research Laboratory* (90):39-43. (English translation by the National Marine Fisheries Service, Southwest Fisheries Center, Honolulu Laboratory. Translation No. 46.)

Rowley, M. 1983. Guide to handling chilled fresh tuna for export to Japan. *Aust. Fish.* 42(3):20-22.

Siebert, G. 1958. Protein-splitting enzyme activity in fish flesh. *Experimenta* 14(65).

Taniguchi, H. 1977. How to effectively kill tuna in order to maintain quality and higher prices. *Suisan Sekai* 9:52-57. (English translation by T. Otsee, National Marine Fisheries Service, Southwest Fisheries Center, Honolulu Laboratory. Translation No. 25.)

Williams, S.C. 1986. *Marketing Tuna in Japan.* First Edition. Queensland Fishing Industry Training Committee.

Yuen, H.S.H. 1979. A night handline fishery for tunas in Hawaii. *Marine Fisheries Review* 41(8):7-14.

Credits

Layout and design	Hirata/Nonaka Creative Advertising
Illustrations	Susan G. Monden

To order copies of this handbook, contact:

University of Hawaii
Sea Grant College Program
Communications Office
1000 Pope Road, MSB 200
Honolulu, HI 96822

Telephone: (808) 948-7410

Copies are $4.00 each.
Send payment with request, if ordering by mail.