4. The use of ice and chilled seawater on fishing vessels

4.1 INITIAL CAPTURE AND IMMEDIATE HANDLING ON BOARD

In order for the best-quality fish to be available to the consumer, care must be taken to reduce spoilage at all stages. Spoilage begins as soon as the fish dies, so it may begin before the fishermen lift the fishing gear out of the water. For instance, the common practice in many countries of leaving gill nets to "soak" for long periods causes a high percentage of loss, over 25 percent according to some studies by the Bay of Bengal Programme (BOBP) (FAO, 1991). Fishing with hand lines, beach seines and other active gear tends to produce good-quality fish, as there is no "soaking" period of the gear. One way of combating initial spoilage in gill nets is to haul nets more frequently. However, these suggestions can be resisted by fishermen because they require more effort, may cost more and may take them away from other activities.

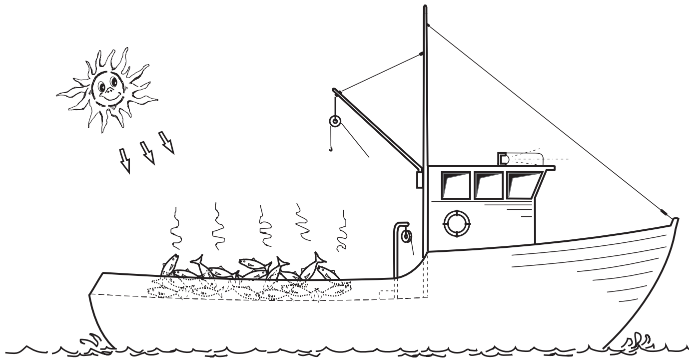
Hence, the use of ice in itself is no guarantee of a better product unless proper handling procedures are fully implemented before the fish are actually stowed in the hold on ice. Even when fish nets or other gear are hauled more frequently, rapid spoilage can take place, especially if the catch is left lying around on deck in the sun and heat for any length of time, thus negating any gain in quality from more frequent hauling periods.

The spoilage processes are continuous and cannot be reversed; no amount of icing will convert poor-quality fish back into a good-quality product.

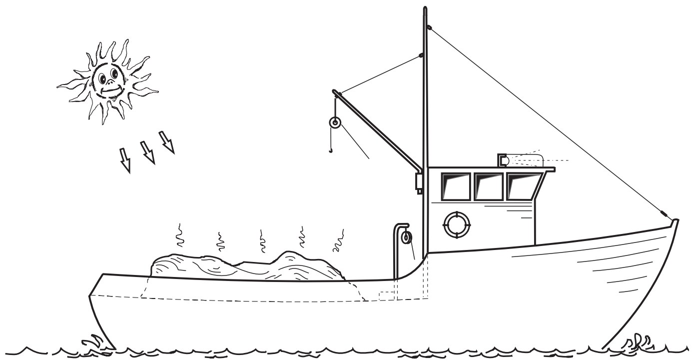
In summary, the time between the capture or death of the fish to when they are properly iced must be as short as possible, with minimum exposure to high temperatures. In tropical conditions, this would also require that fish be kept in the shade and out of direct sunlight. Where it is not possible to ice fish immediately, wet sacking is sometimes spread over the fish awaiting storage. Also, on some fishing vessels it is common to have a fixed or temporary canopy over the working deck (see Figure 4.1) which serves as a sun shelter for the crew and for the catch waiting to be processed prior to stowage in the fish hold.

Without insulation in the fish hold, the rate of ice meltage and loss is likely to be high, particularly in tropical and subtropical regions. Heat infiltration and consequent spoilage of the catch caused by excessive ice melting is most pronounced near the vessel sides and deckhead, as illustrated in Figure 4.2. One way of combating this without insulating the hold is to place plenty of extra ice against the vessel sides before stowing the fish, and extra layers of ice on top of the last layers of fish near the deckhead, which should help compensate for heat penetration. Though insulation installation may appear costly initially, it may repay itself over a period of time by saving ice and bringing better prices for better-quality fish.

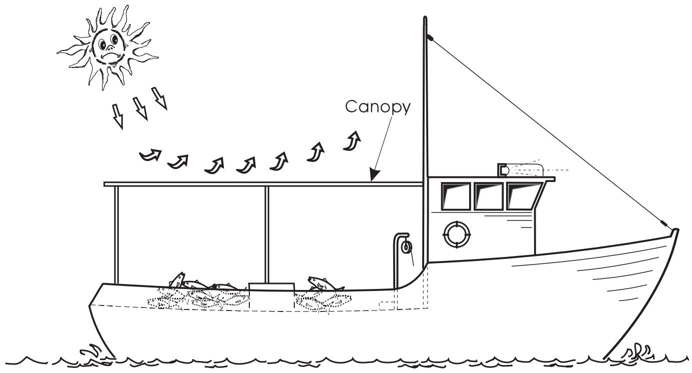
FIGURE 4.1
Protection of catch against heat from the sun



a) Poor practice
Fish left on deck in direct sun, no cover

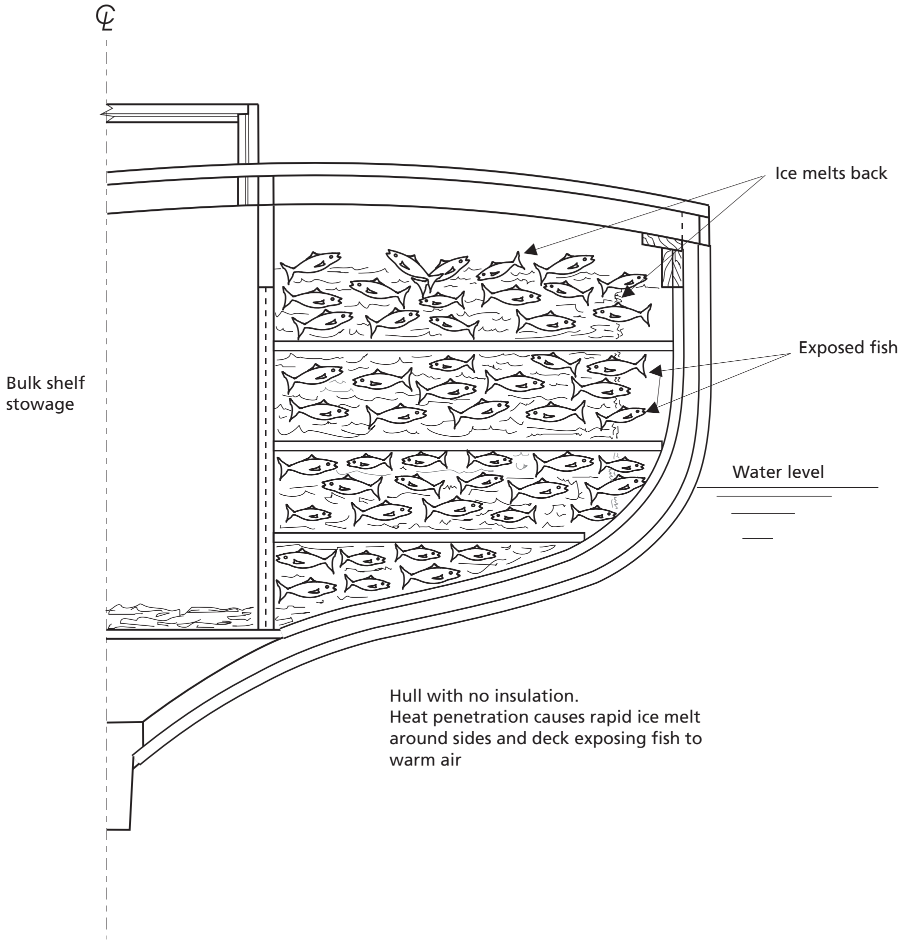


b) Better practice
Fish on deck covered with wet sacking or tarpaulin while awaiting stowage



c) Best option, if mode of fishing permits.
Canopy may be fixed or temporary, painted white for maximum reflection of sunlight

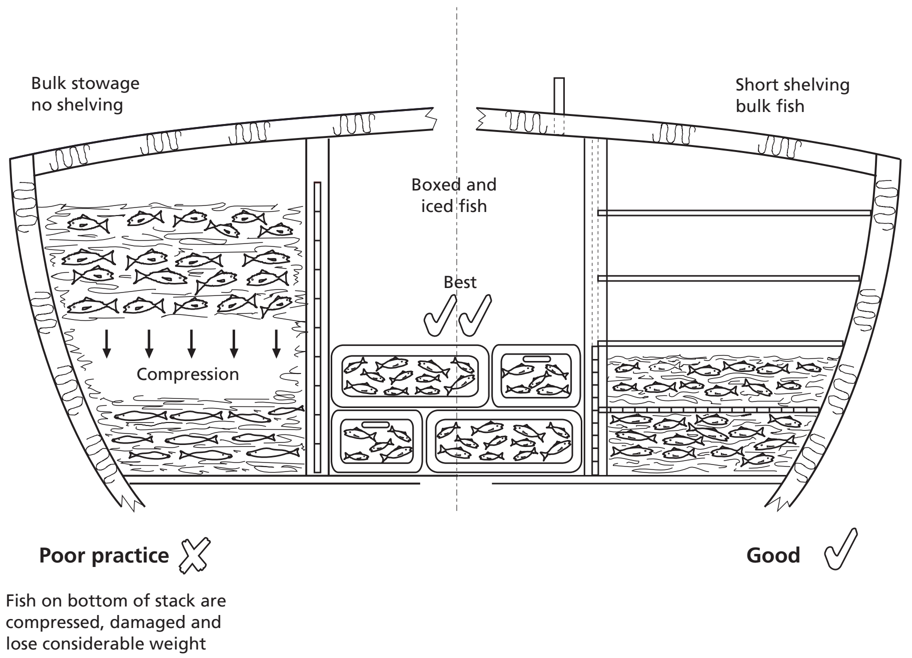
FIGURE 4.2
Half-section of fish hold showing ice melt from heat infiltration



For optimal use of ice, the following points should be taken into account:

- All ice used must be clean and of small particle size for maximum contact. Block ice must be finely crushed to prevent large particles from damaging the fish.
- The proper ratios of fish to ice must be observed. In temperate climates, one part fish to one part ice is common. In tropical conditions, one part fish to three parts ice is not unusual.
- Areas of heat penetration into the hold, such as the engine room bulkhead and hull sides, must be given extra layers of ice to compensate for rapid ice loss in these areas, particularly if insulation is poor.
- The last layers of fish near the deckhead should have extra layers of ice to fully cover the fish and allow for any extra melting from heat penetration through the deck.

FIGURE 4.3
Stowage of bulk fish on ice



- Fish and ice must be carefully and evenly stowed to allow even distribution of both. Shelves and boxes must not be overfilled or crushing damage to the fish will result.
- Fish temperatures at the dockside when discharging should be between 0 °C and 2 °C, and there should also be considerable amounts of ice still evenly distributed among the fish.
- Ice must be layered under, around and on top of the fish.

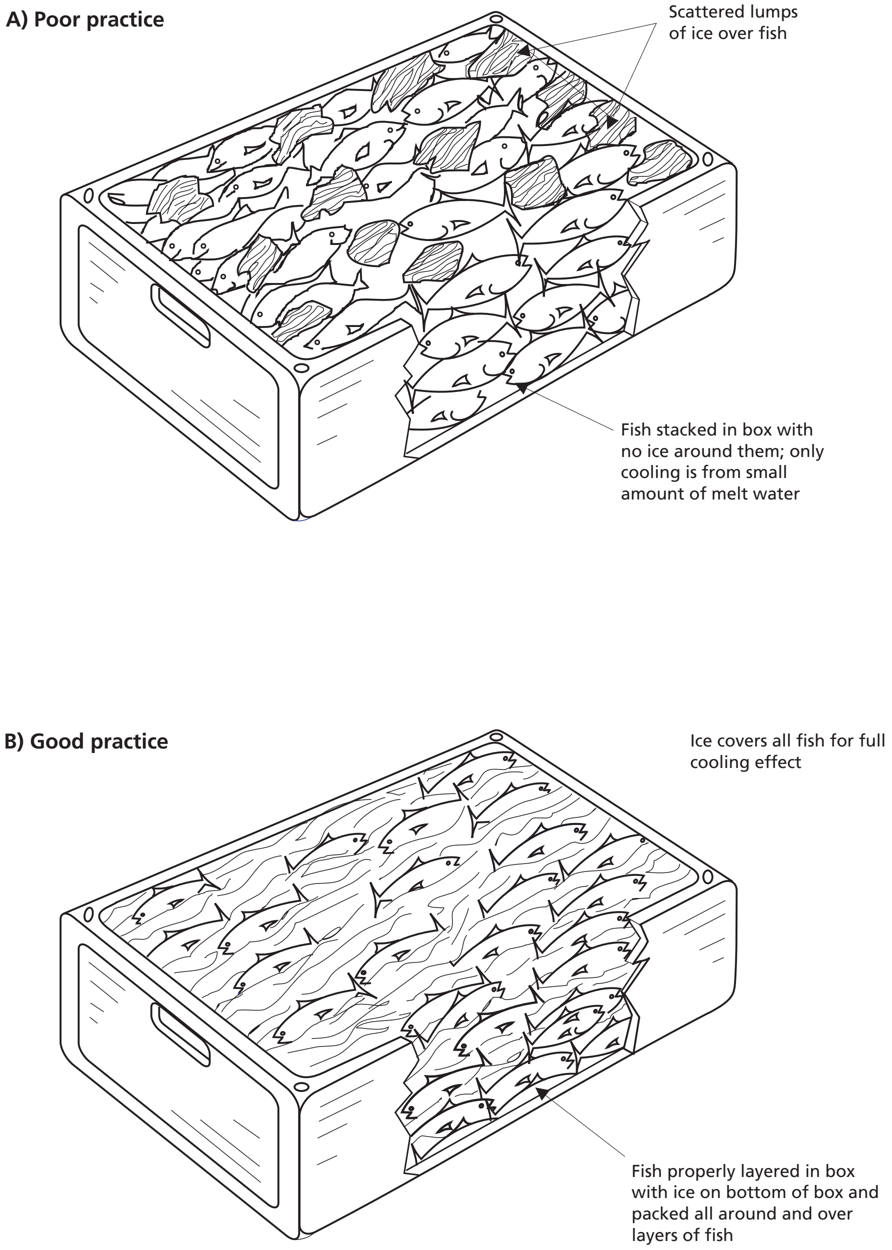
Figure 4.3 illustrates common bulk fish stowage methods in a typical small fishing vessel hold.

4.2 FISH STORAGE CONSIDERING TYPE OF ICE USED

The type of ice used in any particular fishery will generally depend on what is available locally from shoreside ice plants. Ice plants that are built specifically for fishery operations will usually supply subcooled flake or shell ice, or block ice. In some countries with newer plant installations “slush ice” may also be available.

For efficient and rapid cooling, ice must be used correctly. It is important to completely surround the fish with ice so that it is in full contact with the product. For this, ice needs to be in very small pieces or in slush form, or perhaps made into an ice-water slurry as in CSW applications. A few large lumps of ice scattered over the fish do not have the same cooling effect as small particle ice packed around the fish. Whether in boxes or stowed in bulk in fish-hold pens, fish also need to be carefully layered in ice. Improperly and properly iced boxed fish are shown in Figure 4.4.

FIGURE 4.4
Typical plastic fish box/tote (stackable)



In order to optimize the chilling power of ice, some small-decked fishing vessels operating in warm climates have insulated tubs installed on deck. The tubs are filled with ice and CSW and are used for the rapid cooling of freshly caught fish prior to stowage on ice in the hold. An advantage of this system, even though it uses ice to chill the seawater, is that less ice is required in the hold to chill the fish down to 0 °C so, where hold size is a limiting factor, more fish can be stored. Because fish can be chilled almost immediately on capture, this system is capable of producing better quality fish.

4.2.1 Block ice/crushed ice

Block-ice plants are still commonly found in many countries because they are relatively simple to operate and maintain. Often, these plants were built to supply local stores, bars, market places and domestic households as well as the fishing industry.

Block ice is preferred by fishermen in many parts of the world because it will last longer and takes up less space in the fish hold. However, as already mentioned, for block ice to be used effectively for stowage of fish, and to make full use of its cooling power, it first has to be crushed or ground into small pieces. Common practice in many countries is for the ice to be transported and stored as blocks, and ground into pieces as required. In order for the broken ice to make good contact with the fish it must be broken into small enough pieces. In many instances the ice is broken into smaller pieces by simply using an ice pick or hammer. Generally this does not break the ice sufficiently for it to make good contact with the fish and thus the fish can still be exposed to high ambient temperatures. A much more effective means of crushing block ice is to use a mechanical grinder or crusher that can reduce block ice to small pieces of 1 cm × 1 cm or smaller, as described in section 3.3.

4.2.2 Flake ice

Flake ice has the advantage over block ice of being relatively easy to use since it does not need crushing before use. Because it is slightly subcooled during manufacture and can be packed well around fish, it may be more efficient in cooling fish than crushed block ice. However, because it has a higher surface area and holds a lot of air, it takes up more room in storage and melts more quickly than uncrushed block ice.

4.2.3 Slush ice

Slush ice is an extremely efficient cooling agent for fish. It is capable of reducing fish temperatures to 0 °C very rapidly. This type of ice is mostly used to stow fish in closed containers such as boxes or insulated tubs. Its use for stowage of fish on shelving depends on the texture (liquidity) of the ice. Too much water in the mix will tend to run off the shelves leaving the fish exposed. This liquidity factor can be controlled by the operator if the vessel has an ice machine installed. Otherwise the ice has to be loaded in dry form and clean seawater added as required. This ice is finding acceptance with vessels engaged in fisheries for high-value species such as shrimp, where shrimp are loaded directly into large insulated tubs with slush ice at capture and delivered to markets or the processing plant with no further packing and therefore little or no damage to the product. In many ways this ice has similar characteristics to cooling with CSW.

4.2.4 Chilled seawater

CSW is very efficient in cooling because the fish are completely surrounded by the cooling medium. However, it requires watertight boxes or tanks installed in the hold that can incur extra costs, which cannot always be justified. This type of installation is mostly used for:

- fisheries dedicated to capture of high-value species;
- the preservation of fish where there is a relatively short time between capture and delivery to the processing plants, such as that for sardine and anchovy;
- the preservation of bulk catches of small pelagics (for example) where it is impractical to ice fish individually. In this case, fish can often be loaded directly from the purse seine into the CSW hold thus providing rapid and efficient chilling.

The use of tanks also produces a reduction of available hold space, in some cases by as much as 20 percent.

Typical ratios for mixing ice, water and fish in insulated tanks or tubs will vary depending on the climate. FAO Fisheries Circular No. 773 (FAO, 1984) gives the following figures for temperate and tropical climates:

- Temperate climate: 1 kg water : 1 kg ice : 4 kg fish
- Tropical climate: 1 kg water : 2 kg ice : 6 kg fish

According to the Circular, this is the necessary volume of ice to chill fish to 0 °C. If the fish have already been cooled down, the volume of ice can be reduced accordingly. All other factors being equal, it must be remembered that ice will be required for chilling the water in the system as well as the fish, so in theory more ice will be needed with a CSW system than with a plain ice system.

In its simplest form, CSW is made by adding fresh seawater to ice held in tubs or in subdivided waterproof compartments or in tanks in the fish hold. This system works for short periods, but suffers from the problem of temperature stratification. This is caused by the fact that warm water will rise in the tank and ice and fish will tend to float in the water. Unless the CSW and the fish are agitated, the temperature stratification can cause uneven cooling of fish. Conversely, damage can be caused to the fish if agitation is too violent, so methods have been devised that combine the need to circulate the water in the tank and the need to treat the fish with care. Two common methods used are:

- Compressed air introduced into the bottom of the CSW tank via perforated pipes. The air is usually supplied from an air pump located adjacent to the CSW tanks. The resulting streams of bubbles rising to the surface force colder water from the tank bottom to rise and mix with the upper layers. Due to the large amount of bubbles produced this is commonly known as the "champagne system". This is a relatively simple and economical means of reducing temperature stratification and can be used successfully on small fishing vessels with limited space.

- CSW circulated by water pumps. For this system to be efficient, a filtration system is needed to ensure that there is no clogging of return pipes with fish, fish scales and other debris. For more information and details on this system refer to Chapter 2 of this document.

4.3 WORKABILITY OF ICE OVER TIME

During storage there is a tendency for pieces of ice to freeze together, making it difficult to handle and mix with fish efficiently. Research into this problem has been conducted by the Canadian Federal Department of Fisheries using the following parameters to measure the amount of coagulation:

- pressure necessary to break the ice surface;
- depth of gauge penetration;
- pressure necessary to move a shovel pushed into the ice;
- size of clumped fragments.

The research came to the following conclusions:

- Shell ice: remained completely workable through seven days of tests.
- Flake ice: workable for up to 48 hours, but only workable with difficulty after 96 hours.
- Crushed block ice: virtually unworkable after 24 hours.

In most cases when block ice is used on fishing vessels, it would be carried on board whole and only crushed for use as needed, thus the problem of pieces clumping together would not become apparent.

Table 4.1 gives some general visual physical workability observations regarding the ice types being tested.

TABLE 4.1
Type of ice and visual observations

Hours	Shell	Flake	Block (crushed)
0	Ice shells vary in size (10–100 mm) and approx. 6 mm thick No large clumps, poured loosely into insulated container/box with lid	Ice flakes 30 mm × 2 mm thick Flakes irregular in shape No clumping, poured into insulated container/box with lid	Appears like heavy dense snow interspersed with clear single chunks of ice (10–100 mm) Ice tends to clump (retain) shape of boxes
24	Shrinkage 5 mm from sides Individual pieces retain shape	Shrinkage 10 mm from sides Lost "flakey" appearance Some small clumps Developing glazed crust Somewhat dirty appearance	Surface solid with some single solid fragments
48	Shrinkage 10 mm from sides Individual pieces smaller with pitted surface appearance	Surface essentially solid crust Shovel bent during test	Solid
96	Shrinkage 10 mm + Pieces noticeably smaller Ice tends to stick together but still breaks up and shovels easily	Solid surface Quite dirty surface	Shrinkage 20 mm Solid, odd single fragments and small bits of clumping, snow-like particles Quite dirty
168	Shrinkage 20–40 mm Noticeably dirty No real clumping, breaks up easily	Shrinkage 20–50 mm	(192 h) Shrinkage 30 mm Very difficult to push shovel into ice

Source: DFO Canada, 1993.

4.4 QUANTITIES OF ICE REQUIRED ON BOARD

The amount of storage space required for ice will depend on the size of the vessel, the length of the fishing trip, the quantity of fish likely to be caught and whether the vessel has on-board ice-making facilities.

4.4.1 Chilling the fish

Table 4.2 shows the weight of ice necessary to cool 10 kg of fish to 0 °C from various ambient temperatures. For larger volumes of fish, the amount of ice should be multiplied by the actual weight of fish to be stowed in the hold. For example, at an ambient temperature of 30 °C, a load of 1 000 kg of fish would require 340 kg of ice, or slightly over a ratio of 1:3 ice to fish just to cool the fish to 0 °C. This does not allow for losses due to heat infiltration or extra ice necessary to maintain the fish at 0 °C for the rest of the trip.

TABLE 4.2
Theoretical weight of ice needed to chill 10 kg of fish to 0 °C from various ambient temperatures

Temperature of fish *(°C)*	Weight of ice needed *(kg)*
30	3.4
25	2.8
20	2.3
15	1.7
10	1.2
5	0.6

Source: FAO, 1984.

In practice, therefore, much greater quantities are required to ensure that the fish remains chilled once its temperature has been reduced to 0 °C, and that it can be stored at chill temperature for some time.

It is a generally accepted "rule of thumb minimum" to use an ice to fish ratio of 1:1 in the tropics. In many instances ratios of up to 3:1 ice to fish are used. The main influence on the ratio is the length of the fishing trip.

A more detailed presentation can be found in Chapter 7.

4.4.2 Trip duration and estimated volume and composition of catch

It is of little benefit if the amount of ice loaded prior to a fishing trip only lasts part way through the planned voyage. Therefore, careful consideration must be given to how much ice is actually necessary for the average trip. Several factors should be considered when trying to estimate an adequate quantity of ice per trip, such as:

- planned length of the trip;
- historic average catch per trip;
- type of fish being caught, i.e. large, medium, small or mixed;
- available carrying space, in hold and/or containers;

- anticipated ice losses to heat gain in hold or containers;
- local ambient temperatures.

The market for the fish being caught may also have a bearing on the quantities of ice to be used. For example, if high-value pelagics such as swordfish, yellowfin or bluefin tuna and mahi mahi for export markets are being landed, the requirements for icing may be more stringent than for fish destined for local consumption.

Ideally, there should still be some ice left in the hold after all fish have been discharged at the end of each trip. This will indicate that the weight of ice was correctly estimated. Old ice must never be left in the hold for reuse. It must be discarded and the hold washed down with clean water and sanitized with a chlorine-based or other commercial cleaning agent solution, and surfaces should be scrubbed with brushes to remove any hardened blood or fish slime. Only after the hold has been thoroughly cleaned should ice be loaded for the next trip.

The amount of ice that can be taken on board may be restricted by the space availability for initial stowage before commencement of fishing. A balance has to be struck between ice carried, anticipated catch and catch composition. The latter is important, as stowage rates per cubic metre of hold space vary, not only with stowage method used, i.e. shelving or boxing, but also with the size of fish captured. Tables 4.3 and 4.4 show this relationship. In practice, the ice carried could be expected to exceed the minimum estimated quantities by 30 percent or more, to compensate for heat losses. Uninsulated holds will require considerably more ice.

Example: A vessel with an insulated usable fish hold volume of 6 m^3 is departing on a fishing trip of three to four days, and expects to be catching average- to large-sized fish with a total weight of about 1 500 kg. The fish are to be stowed in bulk. The ice needed for the trip can be calculated as follows:

- $1\,500/10 \times 3.4 = 510$ kg of ice will be needed for chilling the fish to 0 °C (see Table 4.2).
- To mix the fish with ice at a ratio of 1:2 (ice to fish) another 750 kg are needed.
- Another 30 percent has to be added to compensate for heat losses: $30/100 \times (510 + 750) = 378$ kg.

The total amount of ice needed is thus calculated to be 1 638 kg. To be on the safe side, the skipper would load 2 000 kg of ice, which corresponds to an ice to fish ratio of 1.3:1, which is slightly above the "rule of thumb minimum". This quantity of ice would occupy around 4 m^3 in the fish hold (see Table 4.3) when the vessel departs for fishing. When departing from the fishing ground, the fish hold would be filled with 1 500 kg of fish mixed with approximately 750 kg of ice. This would also occupy some 4 m^3 of the fish hold (see Tables 4.3 and 4.4).

The volume required for stowage of a tonne of fish stored under three methods of stowage with a 2:1 fish to ice ratio is given in Table 4.4.

The weight of volumes of ice varies according to the type of ice being used (see Table 4.3 and Figure 3.2). Cooling of the catch depends on the weight of ice used, not the volume, so for equivalent cooling capacity, equal weights of ice must be compared.

TABLE 4.3
Typical stowage rates, materials and methods of stowage

Material	Method of stowage	Stowage rate *(kg/m³)*
Ice, crushed		550
Ice, flake		420–480
Small fish (e.g. sardine or similar)	Without ice	800–900
Small fish (e.g. sardine or similar)	In bulk with ice	650
Small fish (e.g. sardine or similar)	In CSW	700
Average to large fish	In bulk with ice	500
Average to large fish	In boxes with ice	350

TABLE 4.4
Stowage rates for shelf, boxed and bulk methods

Method of stowage	Average stowage rate *(m³/tonne of fish)*	Average stowage rate *(ft³/tonne of fish)*
Shelf (2:1 fish:ice)	4.5	160
Box (2:1 fish:ice)	2.7	96
Bulk (2:1 fish:ice)	2.0	70

Source: FAO, 1990.

4.4.3 Storage considerations

There are various means of storage used on board fishing vessels, depending on the size and type of the vessel.

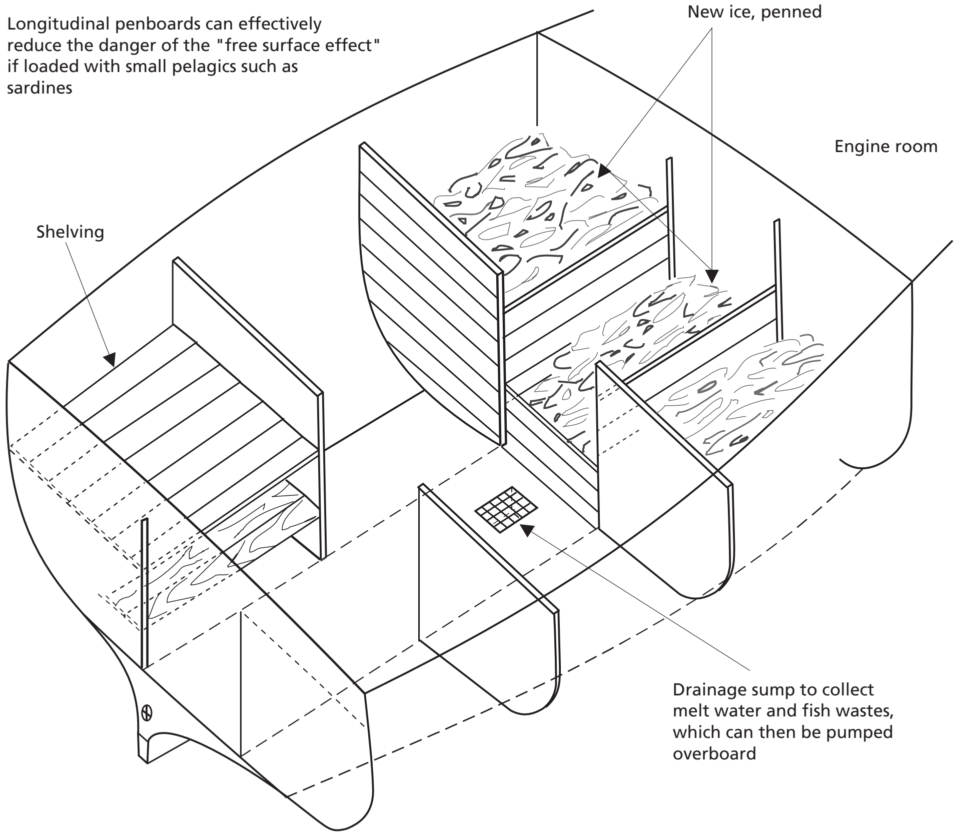
On larger boats using bulk stowage for ice and fish, the hold needs to be properly insulated and is usually subdivided into pens or pounds. The insulation retards excessive ice loss from heat penetration and helps maintain proper icing ratios. Subdivided pens are also necessary to keep unused ice separate from the fish and ice mixture and to allow sorting of catch by size and species as necessary. A typical subdivided fish hold is shown in Figure 4.5.

For decked boats without insulated fish holds, the use of insulated boxes of appropriate size to permit fitting through hatches and to allow manhandling in the hold is a viable alternative to retrofitting the hold with insulation. Tubs do, however, cut down on available stowage space for ice and catch. Again, with high-value species this is less of a problem.

For small open boats, ice is mostly carried in boxes or insulated containers that are used initially to carry the ice, then subsequently to store the catch in ice. Boxes and containers can also be used as shoreside shipping containers if required, thus reducing the need to rebox the fish at landing.

Some artisanal vessels, such as the large canoes of Senegal, require specially shaped boxes in order not to lose too much capacity. This tends to make them unsuitable for other purposes such as dockside storage or shipping containers. On the other hand, section shapes of the typical larger-size dugout canoes found

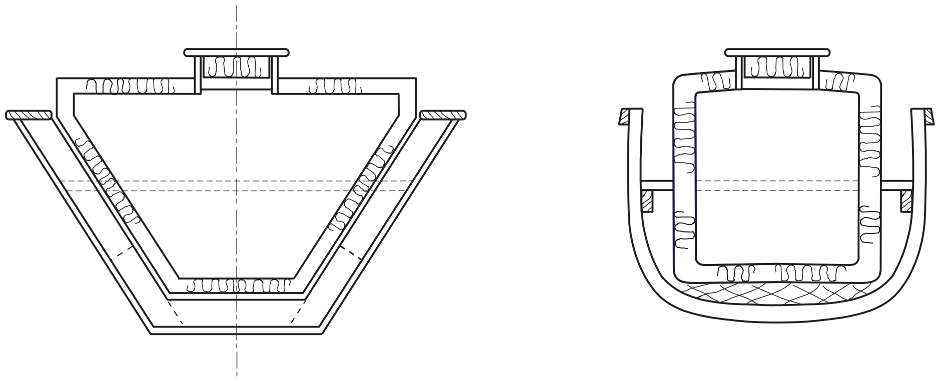
FIGURE 4.5
Typical subdivided fish hold on small fishing vessel



in Central and South America and parts of Africa lend themselves quite well to standard box configurations, which are more suitable for the other uses, as mentioned above (see Figure 4.6).

Small fibreglass fishing vessels have become relatively common in many countries around the world. Mostly they are of the open style with only thwarts and floor area installed, having been produced as multipurpose vessels rather than specifically for fishing. In order to make these vessels more appropriate for fishing operations, some have been adapted to incorporate a small fish hold in the hull. A typical adaptation of this type is shown in Figure 4.7. Many conversions of this type have been made to boats of 25 to 29 ft in length in Central America and the

FIGURE 4.6
Different shapes of canoe fish boxes



A) Fitted fish box for use only in boat (Senegalese canoe)

B) Fish box in large dugout canoe Can be used for shoreside storage and transportation (Central and South America)

Caribbean, so they are already well tested. This type of installation was developed at the request of the fishermen.

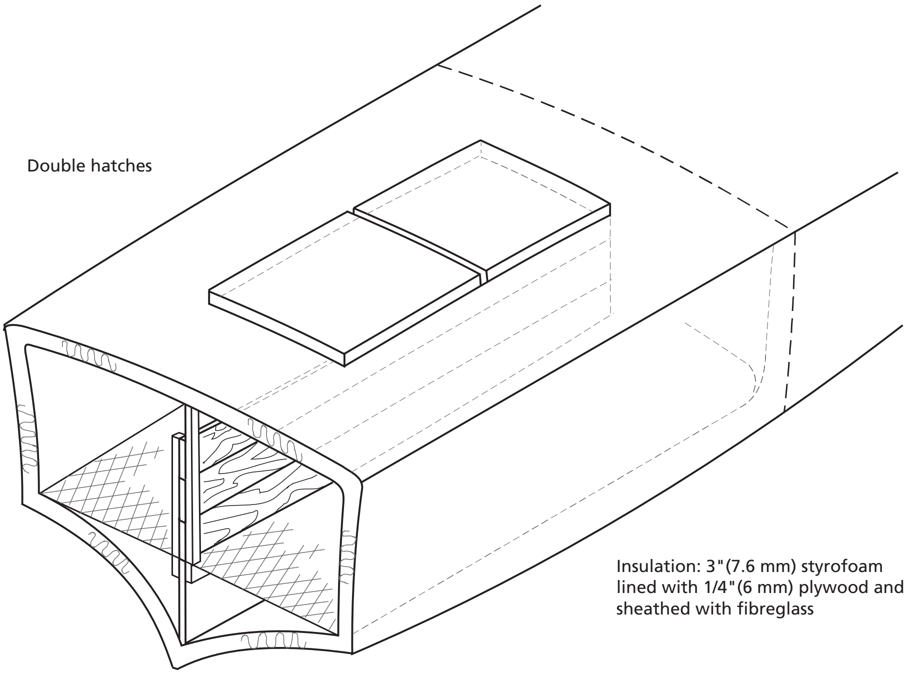
Larger-decked vessels with fish holds generally carry their ice in the hold, where it is kept in hold pens below deck until required for icing the catch. However, some decked vessels in the size range from 35 ft to 55 ft Loa (10.6 m to 16.7 m) load insulated containers full of ice either directly into the fish hold or secure them on deck. These same containers are then used to store part of the catch on ice. By adding clean seawater to the ice in insulated tubs, fish can also be stowed in CSW, which helps prevent the problem of crushing lower layers of fish in the tubs, especially those of large capacity. Stability problems could arise if large heavy tubs are carried on the decks of small vessels, so care must be taken in this regard.

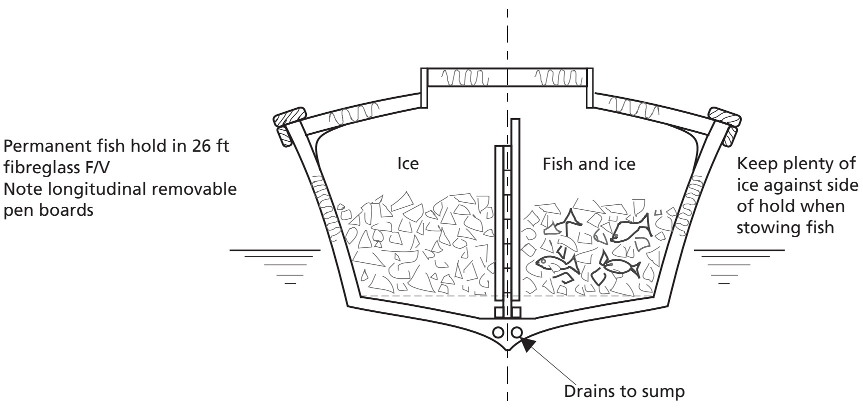
When discharging the catch into containers, the fish can be removed from the hold and transferred directly to the processing plant or market, eliminating handling steps and resulting in a better quality product. With larger boxes or tubs, mechanical equipment may be required for lifting the full boxes from the hold of the vessel and then moving them around on the quayside.

In cases where the ice plant facility is located at some distance from the fishing harbour, the insulated tubs may also be used to transport ice from the plant to the fishing vessels, thus preventing excessive melting losses.

There are several types of insulated boxes or tubs available commercially around the world. These boxes are generally manufactured to be easily stackable with provision for ease of handling, either manually or by slings and/or fork-lift machines. Large insulated tubs are manufactured by “roto-moulding” techniques or by “injection-moulding” processes. Roto-moulding is the most common at

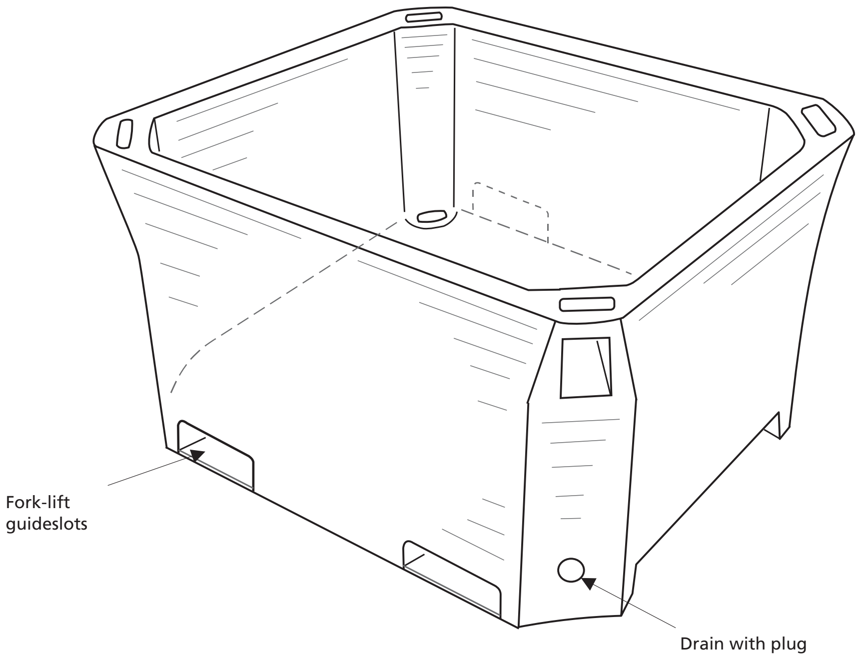
FIGURE 4.7
26 ft fishing vessel with hold space added





Note: Floors are covered by heavy expanded sheet metal, either aluminium or galvanized steel. The mesh is fine enough to prevent flake ice passing through easily, but allows melt water and fish juices to drain into bilges for pumping overboard.

FIGURE 4.8
Typical fishtub and plastic fish boxes

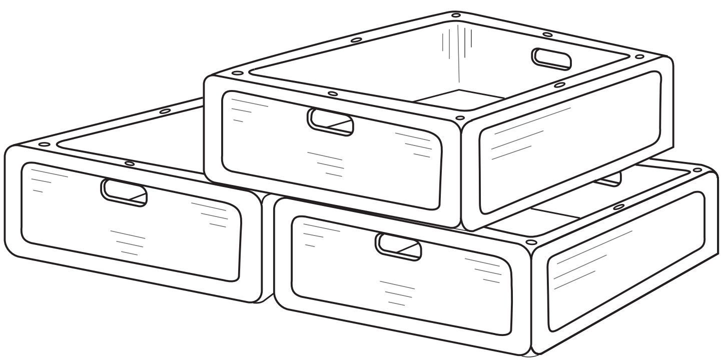


A) Typical insulated tub, capacity 666 litres, injection-moulded

Notes: The provisions for lifting hooks and pallet jacks or fork-lift trucks are moulded integrally.
Tubs are also provided with tight-fitting insulated lids and can be stacked.

Source: Saeplast, Iceland

Boxes of this type range in size from approximately 300 to 1 000 litre capacity



B) Plastic tote boxes for iced fish

Fish packed in ice in boxes usually maintain quality for longer periods than if kept on shelving or in bulk.

Plastic tote boxes are designed to be fully stackable and drain outside the lower boxes, if stacked directly on top of each other. In staggered stacking, this feature does not work properly.

present, as it is generally more economical to produce the shells; however, the manufacturing process does not lend itself easily to mass production methods. Insulation is generally of polyurethane foam, which is injected into the completed plastic shells.

Injection-moulding requires much more expensive tooling that can only be used for one size of tub. Other sizes or shapes require separate moulds. One advantage claimed for injection-moulding is that it is more readily adapted to mass production methods and tub shell thickness can be more accurately controlled.

The sizes of these tubs range from small units of about 60 litre capacity to large 1 000 litre units, with various intermediate sizes also available for different applications. Smaller units can be handled manually when partially loaded; larger tubs require mechanical means for handling such as simple pallet jacks, which can also be used on board, fork lift trucks and/or the vessel's own cargo boom and winch. Some typical types of insulated plastic tubs are shown in Figure 4.8.

Rather than using insulated containers or tubs, it is also common practice to use non-insulated (often plastic) fish boxes stacked inside the insulated hold for storage of fish and ice. These enable fish to be carefully iced and the catch to be separated into different sizes and types of fish before icing. Once boxed, the fish can then be removed from the hold in the boxes and transported to processing plants or markets without further handling. Suitable boxes are made in a variety of shapes and sizes for different applications. Boxing in this way tends to be less economical on space than other means of stowage but this is often compensated for by the convenience of this type of storage.