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BYCATCHES IN PURSE-SEINE FISHERIES

by Martin A. Hall

In this review, I will not attempt to summarize all that is known about bycatches in purse-seine fisheries, but only to address some of the common traits of most problems with this type of gear. The readers are directed to Alverson et al. (1994), for additional information. The scientific names of all species mentioned are listed in Appendix 1.

As opposed to passive gears that are deployed in a habitat that is deemed favorable to catch fish, purse seines are deployed "on fish." When a set is made, the fishermen almost always know that they are encircling a school of fish, and they have a pretty good idea of the species encircled and of the sizes of fish in the school. The accuracy of this information changes from fishery to fishery and from species to species, and may be affected by oceanographic or meteorological factors. In spite of this, there are bycatches of non-target species and/or of unmarketable individuals of the target species.

From the point of view of the bycatch, it is necesary to distinguish the purse-seine fisheries that produce fish for canning or fresh consumption from those that produce fish for the reduction industry.

Because of the characteristics of the product, fishmeal plants can utilize a wide variety of species, even the catch of non-target species can be utilized and becomes a "catch." Practically all sizes caught can be utilized, so there is no discard of unmarketable fish (Guillory and Hutton, 1982). The fact that almost everything can be utilized doesn't mean that there is no ecological impact from some of those captures. It can be argued that to utilize for making fishmeal, species that could be used instead for direct human consumption is a sub-utilization of a resource. Also, the takes of juveniles or small-sized individuals of species of commercial value that may be captured with the target school, are a form of growth-overfishing. Apparently, the larger species incidentally caught in some reduction fisheries are discarded at sea or while unloading (Guillory and Hutton, 1982), so it is not possible to assess this impact.

When the object of the fishery is the canned or fresh-fish market, the fishermen have to be more selective. In some cases, undersized fish of the target species require more labor, and that affects the production costs, to the extent that some canneries cannot afford to process the smaller sizes. Or they may not be acceptable to the consumers. Most non-target species cannot be used in the cans, and their utilization depends on the existence of a market for them. If there exists such a market, and the price per ton is not much lower than the target species, then they can be retained and sold, becoming part of the catch. Unfortunately, in many cases there are no markets for some species, or the price differences are too high to justify the loss of space in the vessel wells, so they are discarded at sea.

From the ecological point of view, the bycatch in purse-seine sets comes from two sources: (a) the "associated" bycatch, composed of individuals that were swimming (or feeding, or resting, or any other behavioral pattern) in association with the target species, and (b) the "chance" bycatch, composed of individuals that happened to be in the area enclosed by the net or wandered into it during its deployment.

Examples of the first type are the sharks and billfishes that are caught with tunas and dolphins in the eastern Pacific Ocean; the types of association include both temporary and long-lasting ones, and the relationships involved in the association include predators that were feeding on the target species, competitors that were feeding on the same prey items, small-sized conspecific individuals that were part of the same school, members of polyspecific aggregations (Au, 1991), prey that were being consumed by the target species, etc. As most fish schools have some degree of size segregation, it is unusual to find a broad range of sizes in the same school, but fish smaller than the smallest size that is accepted by the market may be within the range present in the school, and that will generate discards from the catch. Another situation leading to the capture of a mixture of sizes is the encirclement of two or more schools that may be associated in a temporary way around a food source, as a response to predators or other perceived threats, or to some oceanographic feature.

Examples of the second type of bycatch include sea turtles, the proverbial innocent bystanders, caught in sets on tunas associated with dolphins. For small purse seines, the second type may be low, but for large nets (e.g. 1.5 km long and 200 m deep) the volume enclosed is so large that those chance captures may occur frequently.

The mortality of purse seine-caught animals is caused by asphyxiation due to crowding in the sack of the net, entanglement in the net, and asphyxiation on the deck of the vessel. Air-breathing animals may also become trapped in some portion of the net beneath the surface of the water and asphyxiate. Occasionally animals which are alive, but entangled in the net, may be carried toward the power block and fall from there to the deck, which is likely to injure or kill them.

SOME EXAMPLES OF BYCATCHES IN PURSE-SEINE FISHERIES

There has been a problem with dolphin bycatches in the tuna purse-seine fishery of the eastern Pacific Ocean since the late 1950s. For reasons still unknown, yellowfin tuna swim with some dolphin species. The most common way of fishing in that area is to encircle a group of dolphins to capture the tuna school that is associated with it. In the early years of the fishery, the levels of incidental mortality of dolphins were high (average of about 350,000/year during the 60s),which caused declines in most of the dolphin populations involved. The fishermen soon found ways to reduce the incidental mortalities, and the levels of mortality dropped to 20,000 to 40,000 in the early 80s. More recently, more effort on dolphins, and the incorporation of many skippers and crews that had no experience in this way of fishing caused the mortality to increase again, peaking in the mid 80s. The last few years have seen a decline of about 97 % in mortality, from 133,000 in 1986 to 3,600 in 1993 (Lennert and Hall, In Press). Most of these improvements came from the development of a series of modifications of the purse-seine, and the application of sound techniques to release the dolphins encircled (NRC, 1992; Joseph, 1994).

The changes include technology and procedures:
- 1) different mesh sizes in some portions of the net,
- 2) an additional maneuver after encirclement, the "backdown",
- 3) the use of towing speedboats and a skiff,
- 4) the use of a dolphin rescue raft,
- 5) a different tying up of the corkline,
- 6) the addition of a floodlight on the vessels,
- 7) the use of a jet engine auxiliary boat,
- 8) .. new concepts are being tested at this time

And also education and training to improve the decision-making of the skippers and the special skills of the crews:

- 1) training of speedboat and skiff drivers,
- 2) training of raftperson,
- 3) training of deck boss and crew in the handling and maintenance of the equipment,
- 4) training of skipper and crew on the backdown maneuver,
- 5) training of skippers to identify the risk factors that lead to high dolphin mortality, and the counteractions required.

The reasons to include a long list of rather specific information are: I) illustrating the variety of changes that can be tried; II) showing that even though some developments were more influential than others, there was no magic solution, but an accumulation of small and large changes over decades; III) that technology alone did not solve the problem; IV) that the process is still moving forward. From the beginning of the fishery, when annual mortality was, on average, close to 350,000 to the level of 3,600 in 1993, the reduction in bycatch was 100-fold. But it wasn't fast, it wasn't easy, it wasn't cheap.

In recent years the dolphin populations have remained stable (Anganuzzi and Buckland, 1994).

Another common way to purse-seine for tunas is to use the association of tunas with floating objects of different types. Again, for reasons unknown to scientists, tunas of some species (e.g. yellowfin, skipjack, and bigeye) associate during the night with drifting objects. Besides the tunas, other species of fishes, invertebrates, reptiles, etc., associate with these objects, forming characteristic communities. This way of fishing is common in all oceans of the world (Fonteneau and Hallier, 1992), and different studies (Habib et al., 1982, Hampton and Bailey, 1993, Scott and Anganuzzi, In Press, Hall, In Press) show that the communities involved are quite similar in composition. Typically they include mahi-mahi, wahoo, several shark species (silky, whitetip, hammerheads), several ray species (manta, stingray), yellowtail, rainbow runners, several billfishes (black, blue, and striped marlin, swordfish), several small tuna species (frigate and bullet tuna, black skipjack, triggerfishes, sea turtles, etc. When a set on a log is made, many of the species listed above are caught incidentally. Table 1 (see paper on Classification of bycatches ...) shows the ecological costs, in terms of bycatches, of producing 1000 tons of yellowfin tuna in different types of sets (associated with dolphins, with logs, or not associated). It illustrates the dangers of making decisions without complete information, and focusing on a single problem. The reductions in dolphin mortality that can be achieved by switching the mode of fishing, have a counterpart in the increase of the bycatches of many other species. To assess whether the alternatives are "better" from the ecological point of view requires a large amount of information which is not currently available (abundances and conservation status of different species, mortality rates from different sources, recruitment rates, etc.)

HOW TO IMPROVE THE SELECTIVITY OF A SEINE

The first step toward improving selectivity in purse seines is to increase the amount and quality of the information available to the fishermen before deploying the net. Better information on the species and size composition of the schools to be encircled should lead to better decisions concerning whether to deploy the net, or in the deployment itself. This information may be acquired by visual means (e.g. helicopter overflights) but more likely by acoustic techniques. Better sonars, that are affordable to the fishermen, should result in significant improvements.

Another way to contribute to this goal is to identify areas that are consistently problematic and to avoid them. Areas with large numbers of juveniles of the target species, or of some other species could be closed to fishing, or could be avoided voluntarily.

Another way is to identify modes of fishing that have higher incidences of bycatches than others, and reduce their frequency.

HOW TO IMPROVE RELEASE FROM A SEINE

After encirclement, the characteristics of the net play a major role in reducing bycatches. Several experiments showing the impacts of different mesh sizes and of different types of mesh (square, hexagonal, diamond-shaped) on the escapement of fish which are encircled by seine have been conducted. A recent review can be found in Ben Yami (1994). The regulation of mesh sizes of trawls and other nets has been used for many years to limit the captures to some desirable sizes. However, the fact that some fish escape the net doesn't necessarily ensure that they will survive. Some species, such as mackerel, have little resistance to the physical stresses involved in the capture process, and die soon after release (Pawson and Lockwood, 1980), while others are much more hardy. These differences highlight the need to back up the management decisions with experiments to determine if the effects sought can actually be achieved.

Perhaps different species, or different size-groups could be manipulated inside the net, to allow their release when it is desired. This type of solution would require a solid knowledge of the behavior of the different species in the net, especially of their horizontal and vertical stratification, and their responses to different stimuli that could be used to herd them or separate them (e.g. air curtains (Smith, 1963, Kim and Choo, 1993), sounds, scents, lights, etc) and also the development of modifications in the net such as zippers (Coe et al, 1984) or the use of rigid grids inside the net to facilitate the escapement of the smaller fish (Beltestad and Misund, 1993). The development of some system that would allow the tranfer of the catch to some kind of floating cage, through a chute where the fishers could sort the catch, would be a major step towards solving many of the bycatch problems in different fisheries. If this transfer could be performed before crowding the fish in the net, those fish released should have high survival rates.

In the case of small cetacean bycatches, some of the techniques and equipment developped in the eastern Pacific fishery to release them from the net could be used in other purse-seine fisheries, some of which have, or are believed to have, incidental takes of dolphins (Northridge, 1984,1991).

The possibility of changing the methods of handling of the unwanted fish after they have been brought on board cannot be discounted. This may work only in the case of the most resistant species, such as sharks, because they must survive not only crowding in the net, but also the crushing in the brailing system and lack of water on their gills on the deck of the vessel.

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Appendix 1

Tunas

yellowfin tuna	Thunnus albacares
skipjack tuna	Katsuwonus pelamis
bigeye tuna	Thunnus obesus
black skipjack	Euthynnus lineatus
frigate tuna	Auxis thazard
bullet tuna	Auxis rochei

Dolphins

spotted dolphin	Stenella attenuata
spinner dolphin	Stenella longirostris
common dolphin	Delphinus delphis

Billfishes

black marlin	Makaira indica
blue marlin	Makaira mazara
striped marlin	Tetrapturus audax
swordfish	Xiphias gladius
sailfish	Istiophorus platypterus

Sharks and rays

silky shark	Carcharhinus falciformis
blacktip shark	Carcharhinus limbatus
whitetip shark	Carcharhinus longimanus
hammerhead shark	Sphyrna spp.
manta ray	Manta spp. and Mobula spp.
sting ray	fam. Dasyatidae

Other large pelagic fish species

mahi-mahi	Coryphaena spp.
wahoo	Acanthocybium solandri
yellowtail	Seriola spp.
rainbow runners	Elagatis bipinulatus
triggerfishes	fam. Balistidae

Sea turtles

olive ridley	Lepidochelys olivacea (the vast majority)
leatherback	Dermochelys coriacea
loggerhead	Caretta caretta
hawksbill	Eretmochelys imbricata