BYCATCH IN THE TUNA NET FISHERIES

Martin A. Hall and Peter G. Williams

Tunas are caught in most oceans of the world with a variety of gears, ranging from handlines used on pirogues to purse seines up to 1.5 km long and 200 m deep used on large vessels. The four gears that produce the greatest catches are purse seines, pole and line, longlines and gillnets. Even though these and other gears are designed and deployed for catching tunas, many other species are taken incidentally in most fisheries. Of these captures, some have economic value and are retained by the fishers, becoming part of the catch. Another fraction is released to the ocean alive. A third fraction, "the part of the capture that is discarded dead," is called the bycatch (Hall 1996). In this brief review of bycatch in the Pacific tuna fisheries, the discussion will focus on purse seines, with only a brief reference to coastal gillnets. Longlines are the subject of another contribution to this symposium. High seas gillnets, recently banned by the United Nations because of high bycatch in some areas, will not be included. A major study of the issue of bycatch in world fisheries (Alverson et al 1994) has been published recently, and readers are referred to that work for the overall background and for many insights on the subject.

Purse Seines

These nets are deployed by encircling a school of tunas with a vertical wall of webbing, after which a cable passing through rings attached to the lower edge of the net is pulled to close the "purse." After the purse is closed, the net volume is reduced by retrieving most of the net, until the catch is limited to a small volume by the side of the vessel. A large scoop, called a brailer, is used to bring the catch on board. The operation is called a "set." Purse seining is a selective way of fishing because the net is deployed on fish that have been identified as the target species and, in many cases, after gathering information on the size composition of the fish. However, the school encircled may contain a mixture of sizes, and/or species, that results in the capture of unwanted individuals. During the set, the catch is crowded into a small volume that results in physical injuries and subsequent mortality to all but the most rugged individuals.

There are three basic types of sets, depending on the way the school is detected: (1) if the school is detected from evidence on the surface of the water, the set is called a "schoolfish set"; (2) if the tunas are detected while they are associated with a floating object, the set is called a "log set"; and (3) if the school is detected through its association with a herd of dolphins, the set is called a "dolphin set." Only some species of dolphins are involved in this association, the main ones being the spotted dolphin, the spinner dolphin and the common dolphin. Further classification of sets can be used, separating sets on artificial floating objects deployed by the fishers from those on other floating objects, or sets on whales or whale sharks from other "floating objects."

Schools caught in these ways include the main target species: yellowfin, skipjack and bigeye tuna, and sometimes other smaller tunas (e.g., black skipjack, are bullets, and/or frigate tuna). The composition of the catch from the types of set are different. In the eastern Pacific Ocean (EPO):

- log sets frequently include a mixture of yellowfin and skipjack and sometimes also bigeye tunas, usually of the smallest sizes in the fishery (e.g., yellowfin tuna with a modal length of 45 cm);
- schoolfish sets can consist of pure yellowfin (modal length of 55 cm) or skipjack or mixed groups of these species, with lower proportions of bigeye; and
- dolphin sets, composed almost exclusively of larger yellowfin tuna (modal length greater than 100 cm).

In the western and central Pacific (WPO), west of 150° west longitude, the species and size composition of catches from log and schoolfish sets are similar to those described for the EPO, although WPO schoolfish sets can also include pure schools of the larger yellowfin tuna.

Dolphin sets are extremely rare in the WPO.

The relative proportions of these set types show differences among fishing areas. The association between tunas and dolphins is much more frequent in the EPO than in all other areas. In the WPO, there have been few reports of sets involving dolphins in the main area of purse-seine activity (Bailey et al 1996). In the Philippines, a "municipal" purse seine fishery operates on tuna schools associated with "payaos" rafts constructed by the fishermen (Dolar 1994) and, according to scattered accounts by crew members, dolphins have been killed during these operations, but the information is not adequate to estimate the amount of dolphins killed. It appears that the dolphins and the tunas are both associated with the payaos, rather than with each other. The tuna/dolphin association is present in other areas (Francis et al 1992), and occasionally sets are made on these groups, but the frequency of occurrence seems to be much less than in the EPO. The other two types of sets are common everywhere and their proportions are shown in the following table:

Table 1 - Percentages of sets by type in different oceans. Sets on FADs, whales and whale sharks are included in the log set category.

	Dolphin sets	Schoolfish sets	Log sets
Eastern Pacific			
1986-94	42-76	12-40	10-22
1996	43	25	32
Western & Central Pacific			
1991-96	0	55-63	37-45
Eastern Atlantic			
1976-82	1.4	62.2	36.4
Caribbean Sea			
1987-89		53	47
Western Indian Ocean			
1986-87		44	53
1986-91		38	63

Sources: Eastern Atlantic – Cayre et al 1988; Caribbean Sea – Medina-Gaertner and Gaertner 1991; Western Indian Ocean – Sabadach and Hallier 1993

Species Composition of the Bycatch in Different Set Types

The principal source of information on bycatch is data collected by observers. The observer coverage in the eastern Pacific is 100% for vessels with carrying capacities of more than 400 short tons, but only about 5% for the WPO, and lower in other oceans.

One of the main differences among the set types is the mobility of the group captured. In dolphin sets in the EPO, the group composed of dolphins, large tunas, sharks and billfishes is capable of moving at relatively high speeds, and it is subject to a chase of about 10 minutes to more than 1 hour prior to setting. As a result, only the larger (faster) individuals can keep up with the group, and the catches are composed of almost all marketable sizes of tunas (discards of 0.5-1.7% in 1993-95), plus a few individuals of other species (the more important are the sailfish, blacktip shark, yellowtail, and dorado or mahi-mahi).

School sets are normally made on groups in motion, although occasionally a group in a feeding frenzy may seem to be quite static. The tuna discards are slightly higher, that is, 3.0-6.6% for the EPO during 1993-95. Due to lack of adequate observer coverage, only broad indications of the level of bycatch and tuna discards are available for the WPO. Tuna discards from school sets in the WPO have been estimated at about 2% of the total catch by weight (1995-96 WPO observer data). However, observer accounts indicate that various factors, such as differing discard practices among fleets and vessels, indicate that discards of tuna should be treated as an irregular and unpredictable feature of the WPO fishery.

The main species taken as bycatch in EPO school sets are: sailfish, dorado or mahi-mahi, wahoo, blacktip sharks, manta rays and the pelagic sting ray. In WPO school sets, the main species taken as bycatch include: non-target tuna species (kawakawa and bullets), rainbow runner, silky shark, mahi mahi, wahoo and Indo-Pacific blue marlin (Bailey et al 1996; 1995-96 WPO observer data).

Log sets, on the other hand, are made on drifting objects. Any species or size of fish can be associated with an object that is merely drifting, and the objects usually aggregate large and diverse communities. The tunas that associate with floating objects are the smallest caught in the fishery, and a large portion of them are below the marketable size (discards of 15-25% in the EPO during 1993-95, and an estimated 7% in the WPO purse seine fishery, according to recent observer data).

The community associated with the floating objects includes several tuna species (yellowfin, skipjack, bigye, black skipjack, bullets), several species of billfishes (black marlin, Indo-Pacific blue marlin, striped marlin), sharks (blacktip, silky, oceanic whitetip, hammerhead, pelagic sting rays, etc.) large bony fishes (dorado or mahi-mahi, wahoo, yellowtail), and sea turtles (olive ridley). Besides the species composition, the bycatch of these species show major differences in their magnitude for the different types of set. Two tables are included to describe these differences. Table 2 shows the results on a per-set basis, and Table 3 shows the bycatch produced per 1,000 MT of marketable tunas (yellowfin, skipjack, bigeye). It is clear that the bycatch in log sets are orders of magnitude greater than those in the other types of sets.

Bycatch by Biological Groups

Dolphins

The incidental mortality of dolphins in the EPO has been the object of numerous studies describing the evolution of the problem and its present condition (Francis et al 1992; Joseph 1994; Lennert and Hall 1995). The mortality of dolphins has been substantially reduced, from a recent peak of over 133,000 in 1986 to a current level of around 2,600. Most of this reduction comes from improvements in the gear and techniques used by the fishers, and from regulations setting mortality limits per vessel and other constraints. Research into the causes of the problem has resulted in a series of technological changes, an extensive education program for fishers, and international management actions to require a substantial level of monitoring and to develop sensible mechanisms of control. With the mortality of dolphins at an all-time low, interest has shifted to the impacts of the other ways of fishing.

Table 2 - Average bycatch (#) per set: eastern Pacific 1993-95 combined data; western and central Pacific 1995-96 combined observer data.

	Eastern Pacific			Western and Central Pacific	
Species	Dolphin Sets n=13,869	School sets n=10,107	Log sets n=6,184	School sets (n=1545	Log sets (n=777)
<u>Billfish</u>					
Indo-Pacific blue marlin	0.006	0.022	0.165	(0.062)	(0.071)
Black marlin	0.007	0.020	0.148	(0.063)	(0.079)
Striped marlin	0.007	0.019	0.065	(0.000)	(0.005)
Shortbill spearfish	0.002	0.000	0.001	(0.000)	(0.000)
Unid. marlin	0.004	0.006	0.055	(0.000	(0.000)
Sailfish	0.052	0.114	0.014	(0.010)	(0.006)
Swordfish	0.001	0.003	0.013	(0.006)	(0.000)
<u>Large Bony Fishes</u>					
Mahi mahi	0.063	6.692	190.920	(0.030)	(1.333)
Wahoo	0.019	5.053	94.818	(0.014)	(0.474)
Yellowtail	0.278	1.842	4.788	(0.000)	(0.009)
Rainbow runner	0.001	0.021	3.834	(0.530)	(23.568)
<u>Other Small Bony Fishes</u>	0.004	4.357	2.160	(0.049)	(1.810)
Trigger Fish	0.100	15.309	214.253	(0.333)	(14.694)
Small forage	2.701	11.391	160.048	(0.064)	(12.208)
Other	1.133	8.561	239.158	(1.544)	16.719)

Table 2 continued next page

Dolar (1994) presents some data on a municipal purse seine fishery of the Philippines, carried on by small vessels fishing close to the coast and targeting tunas. The bycatch of dolphins, based on fishers' reports, is estimated at roughly 1 dolphin per 2 tons of tuna caught. She estimates the total dolphin mortality caused by the purse seiners operating from one port of the Philippines to be 2,000-3,000 dolphins per year. In comparison, the rate of mortality in the EPO tuna fishery is roughly 1 dolphin per 40-50 tons of tuna, and the total mortality for the whole international purse seine fleet was around 2,600 dolphins in 1996.

In other areas of the Pacific, sightings of tunas associated with dolphins appear to be rare in comparison with the EPO (Pacific Tuna Development Foundation 1977; Bailey 1996). Only in waters off the Philippines and Indonesia, the association may be more common, but its frequency is still far below that observed in the eastern Pacific.

Billfishes

For the billfishes and other categories which will be discussed below, the analyses will be based on the combined database for the 1993-95 period of the EPO fishery, consisting of 13,869 sets on dolphins, 10,107 sets on schoolfish and 6,184 sets on logs. The comparisons within a group will be based on the bycatch per unit of effort (BPUE), measured as bycatch per set, and the relative values of other species will be expressed as fractions of the highest BPUE in a group and in the type of set in question. As noted previously, the coverage of observer data collected in the WPO is currently much lower (estimated to be less than 5% for 1995-96), and as such, only broad indications of billfish BPUE are available.

EPO: Sailfish is, by far, the most abundant billfish in both dolphin and school sets. Next in decreasing order of importance (at levels 80-85% lower) are three species of marlin: blue, black and striped. In log sets the order is reversed; blue and black marlin are the most common, followed at 1/2 the level of BPUE by the striped and unidentified marlins, and sailfish appear at 1/10 of the BPUE level. Shortbill spearfish and swordfish are rarely taken.

Table 2 (continued)

	Eastern Pacific		Central and Western Pacific		
Sharks and rays					
Blacktip	0.500	1.661	5.978	(0.000)	(0.000)
Silky	0.075	0.266	2.093	(0.371)	(0.732)
Whitetip	0.053	0.078	1.257	(0.013)	(0.019)
Hammer-head	0.019	0.122	0.220	(0.000)	(0.000)
Other sharks	0.246	0.198	0.262	(0.000)	(0.095)
Unid. sharks	0.058	0.227	1.485	(0.999)	(3.251)
Manta ray	0.084	0.460	0.022	(0.023)	(0.006)
Sting ray	0.027	0.261	0.049	(0.008)	(0.023)
Sea Turtles					
Olive ridley	0.005	0.008	0.017	(0.000)	(0.002)
Logger-head	0.000	0.001	0.000	(0.000)	(0.000)
Green/ black	0.000	0.001	0.003	(0.000)	(0.000)
Unid.	0.003	0.002	0.006	(0.000)	(0.000)

WPO: The Indo-Pacific blue marlin and black marlin appear to be the most common billfish species encountered in WPO school and log sets. Other species of billfish encountered include (in order of frequency) sailfish, swordfish and striped marlin. (Bailey 1996; 1995-96 WPO observer data).

Sharks and Rays

Elasmobranch bycatch are a source of concern in many fisheries because of their levels, and because of the fact that many shark and ray species are long-lived, take many years to reach sexual maturity, and produce only a few offspring. These characteristics, which are also found in most cetaceans, make these species particularly vulnerable.

EPO: The blacktip shark is the most common elasmobranch taken in all types of sets. In dolphin sets, a variety of sharks grouped as "other sharks" follows at 1/2 the BPUE level, and manta rays, silky sharks at 1/6 the BPUE level are the next pair. In schoolfish sets, the manta ray follows the blacktip shark (at 1/3 of BPUE), and the silky shark and the stingray occur at 1/6 of BPUE. In log sets, the silky shark follows at 1/3 BPUE, unidentified sharks at 1/4, whitetip sharks at 1/5, hammerhead sharks at 1/25, stingrays at 1/100 and manta rays at 1/270.

WPO: The silky shark appears to be the most frequently taken elasmobranch in WPO log and schoolfish sets, followed by oceanic whitetip shark, sting rays and manta rays (Bailey et al 1996; 1995-96 observer data).

Other Large Pelagic Bony Fish

EPO: In dolphin sets, yellowtail is the most common bycatch, followed at 1/5 BPUE by mahi mahi, and at 1/15 by wahoo. In school sets, mahi mahi leads, followed by wahoo at 3/4 BPUE, and an ill-defined category of "other large bony fishes" at 13/20 BPUE. In log sets, the figures are orders of magnitude higher. Around 190 mahi mahi and 95 wahoo are taken on the average set. Much less amounts of yellowtail (1/40 BPUE) and rainbow runner are also taken.

WPO: Rainbow runner appears to be the most common bycatch in WPO school sets. As in the EPO, the amount of large pelagic bony fish bycatch in log sets is higher, with mahi mahi, wahoo and barracuda the predominant bycatch species in this category. (Bailey et al 1996; 1995-96 WPO observer data).

Table 3 – Avg. bycatch (#) to produce 1,000 MT of all tunas: eastern Pacific combined data 1993-95; western and central Pacific combined observer data 1995-96

	Eastern Pacific			Western and Central Pacific	
Species	Dolphin Sets n=13,869	School sets n=10,107	Log sets n=6,184	School sets (n=1545	Log sets (n=777)
Billfish					
Blue marlin	0.4	1.5	5.0	(2.4)	(2.0)
Black marlin	0.4	1.3	4.5	(2.4)	(2.2)
Striped marlin	0.4	1.3	2.0	(0.0)	(0.1)
Shortbill spearfish	0.1	0.0	0.0	(0.0)	(0.0)
Unid. marlin	0.2	0.4	1.7	(0.0	(0.0)
Sailfish	3.0	7.8	0.4	(0.4)	(0.2)
Swordfish	0.0	0.2	0.2	(0.0)	(0.0)
Unid.	0.1	0.2	0.4	(0.2)	(0.0)
Large Bony Fishes					
Mahi mahi	3.6	458.1	5,751.3	(1.2)	(38.1)
Wahoo	1.1	345.9	2,856.3	(0.5)	(13.5)
Yellowtail	15.8	126.1	144.2	(0.0)	(0.3)
Rainbow runner	0.0	1.4	115.5	(20.4)	(673.4)
Other	0.2	298.3	65.1	(1.9)	(51.7)
Small Bony Fishes					
Trigger Fish	5.7	1,047.9	6,454.1	(12.8)	(419.8)
Small forage	153.4	779.8	4,821.3	(2.5)	(348.8)
Other	64.4	586.0	7,204.4	(59.4)	(477.7)

Table 3 continued next page

Sea Turtles

EPO: The most common species of sea turtle taken in all kinds of sets is the olive ridley. The BPUE in log sets is twice that of school sets and more than three times that of dolphin sets.

WPO: Sea turtles have been encountered from time to time in WPO purse seine sets, although observer accounts suggest that they are usually released alive prior to the sacking up process. The hawksbill turtle and the olive ridley turtle have been the most common species encountered by observers in log and schoolfish sets. As in the EPO, the number of turtles encountered in log sets is an order of magnitude higher than in school sets. (Bailey et al 1996; 1995-96 WPO observer data).

Tripper Fishes and Other Small Fishes and Invertebrates

Because of the difficulties assessing the numbers or weights of these individuals, especially when they occur in large aggregations, they will not be discussed here. The vast majority (> 95%) of the invertebrates taken are jellyfishes. In the WPO, this category includes considerable amounts of ocean anchovy, the main forage of free-swimming tuna schools.

Table 3 (continued)

	Eastern Pacific		Central and Western Pacific		
Sharks and rays					
Blacktip	28.4	113.7	180.1	(0.0)	(0.0)
Silky	4.3	18.2	63.1	(14.3)	(20.9)
Whitetip	3.0	5.3	37.9	(0.5)	(0.5)
Hammer-head	1.1	8.3	37.9	(0.5)	(0.0)
Other sharks	14/0	13.6	7.9	(0.0)	(2.7)
Unid. sharks	3.3	15.5	44.7	(38.4)	(92.9)
Manta ray	4.8	31.5	0.6	(0.9)	(0.2)
Sting ray	1.6	17.9	1.5	(0.3)	(0.7)
Sea Turtles					
Olive ridley	0.3	0.5	0.5	(0.0)	(0.01)
Logger-head	0.0	0.0	0.0	(0.0)	(0.0)
Green/ black	0.0`	0.1	0.1	(0.0)	(0.0)
Unid.	0.1	0.1	0.2	(0.0)	(0.0)

Tunas

Not all the tunas caught are retained for sale. Some tuna species, e.g. *Euthynnus* spp. And *Auxis* spp., are not marketable in most places; in other cases, the fish are too small, in poor condition, or the catch of the last set exceeds the remaining carrying capacity of the vessel and it is forced to return part of the catch to the sea. The vast majority of the fish returned to the sea are dead, because crowding in the net is fatal for most individuals. Table 4 shows the average discards and the discard/marketable catch ratios for the main tuna species and for all tuna species combined. For the EPO, log sets result in the largest discards with averages for all tuna species of 6.2 to 9.3 metric tons (MT) per set (discard ratio of 15-25%). For schoolfish sets, the averages are 0.4 to 1.1 MT (discard ratio 3-7%); and for dolphin sets the averages are 0.1 to 0.4 MT (discard ratios of 0.5-1.7%). Skipjack tuna is the predominant species in the discards.

For the WPO, as in the EPO, log sets have a higher discard/marketable catch ratio than school sets (~7% for log sets compared to ~2% for school sets; 1995-96 WPO observer data), and skipjack also constitute the greatest component of total tuna discard.

The similarity in the specific composition of the incidental takes reflects the fact that the pelagic community has common components throughout the Pacific (and the other oceans of the world), and that the proportions of the species in the polyspecific aggregations that are set on are consistent, which probably reflects some ecological characteristic of the system.

Coastal Gillnets

Gillnets, either drifting or fixed, are one of the most widespread gears used to catch tunas. Because of their lower cost, and the possibility of operating them from very small vessels, they are accessible to artisanal fishers throughout the world. The number of gillnet fishers is very high. Northridge (1991) reviewed the driftnet fisheries and provides some examples of the number of vessels using gillnets in several nations and in different ocean basins.

India	>150,000
Indonesia	48,000
Iran	2,600
Korea	14,000
Malaysia	11,700
Peru	>2,500
Portugal	11,000
Sri Lanka	3,500
West Africa	40,000

These figures are included to give an idea of the magnitude of the world gillnet fleet, but they should be considered with caution. As gillnets can be operated from very small boats, which may be departing and landing from isolated beaches, it is not possible to closely monitor the number of vessels operating in an area. Also, many of these vessels operate only during short periods of the year. Not all those vessels target tunas, but many of them do, either as the main target, or as one of multiple targets. There are few studies of the bycatch of these fleets. In the EPO, gillnet fisheries targeting tunas (among other species) operate from Ecuador, Peru and other nations (Reyes and Oporto 1994; Felix and Samaniego 1994). The mortality of dolphins inflicted by the artisanal fleet from Ecuador is estimated to be at least 2,500-5,000, for four important ports, but the total for the nation may be "2-3 times greater than this" (Felix and Samaniego 1994). For Peru, Van Waerebeek and Reyes (1994) estimate a mortality of 15,000-20,000 dolphins per year in a variety of artisanal fisheries, some of which target tunas.

In the Philippines, a small driftnet fishery studied by Dolar (1994) and targeting on yellowfin tuna produces a dolphin mortality estimated at 428 individuals per year.

Several studies have been made of the impacts of gillnets around Sri Lanka. Leatherwood and Reeves (1989) and Leatherwood discuss different estimates of dolphin mortality ranging from 8,000-13,000, in a fishery producing roughly 20,000 tons of fish (most of it tuna) per year.

For other fisheries we have some information on bycatch rates per unit of effort (1,000 km of gillnet per set). Northridge (1991) reviews the literature on the subject and produces the following examples:

Bay of Biscay	~84 dolphins	Goujon 1996
Sri Lanka	14-84 cetaceans	Dayaratne & de Silva 1990
	~76 small cetaceans*	Leatherwood & Reeves 1989
Arafura Sea	33-38 small cetaceans	
	57 dolphins	Harwood & Hembree 1987
	~70 dolphins**	Harwood et al 1984
Yap	126-146 dolphins	Goldblat 1989, cited Northridge 1991
Tasman Sea	60 dolphins	Sharpes et al 1990
	64 dolphins	Coffey & Grace 1990

*computed assuming an average length of net per set of 0.8 km

**computed assuming an average length of net per set of 8 km (range provided 3.4-12 km)

Some of these fisheries are no longer operating, yet they illustrate the fact that when deploying large-mesh gillnets to catch tunas, dolphin bycatch is quite likely. As many small cetaceans have similar size, shape, swimming speed, and share the habitat, and frequently the prey, with tunas, it is logical to expect that they will be caught by the same gears. An interesting observation is that the BPUEs provided by the different surveys, made in a variety of areas and time periods, are remarkably similar.

Conclusions

The results presented here are just a first step toward assessing in full the impact of the tuna fisheries on the ecosystem. Much more data, including longer time series, better coverage in some cases (for example, the WPO), studies of the stock structure, abundance and reproductive rates for the species involved, and trophic relations are needed to complete the picture. Besides these, effort toward finding technological or regulatory solutions to the problems that are identified is a necessary complement.

Some studies have been made for purse seines in other ocean areas, but the scale of sampling is much smaller. For the Indian Ocean, Lablache and Karpinski (1988) mention the presence of bycatch in 71% of the sets. The average discards were 2.4 tons per set, amounting to 6% of the total catch. The composition is given as: tunas 59%, whitetip shark 12%, mahi mahi 5%, triggerfish 5%, billfishes 2%, kawakawa 2%, wahoo 2%, and rainbow runner 1%. Apparently the sample includes a mixture of different set types. For the Atlantic and Indian Oceans, researchers from the European Union have completed a study that will be published soon, including data from observer programs in both areas. A comparative study of bycatch in different areas may be useful to understand the similarities and differences in the pelagic communities involved.

Table 4 – Avg. catch per set, discard per set and discard ratio for the different tuna species, and all combined. Eastern Pacific data for 1993-95; western and central Pacific observer data 1995-96.

	Eastern Pacific			Western and Central Pacific	
	Dolphin Sets	School sets	Log sets	School sets	Log sets
No. of sets	13,869	10,107	6,184	(1545)	(777)
<u>Yellowfin</u>					
Discard/ catch ratio	0.0096	0.0163	0.1619	(0.0352)	(0.0560)
Catch/set	17.49	10.00	6.86	(3.25)	(7.92)
Disc/set	0.17	0.16	1.11	(0.11)	(0.44)
<u>Skipjack</u>					
Discard/ catch ratio	0.0752	0.0921	0.1744	(0.0191)	(0.0795)
Catch/set	0.29	4.24	22.61	(13.71)	(19.85)
Disc/set	0.02	0.39	3.94	(0.11)	(1.58)
<u>Bigeye</u>					
Discard/ catch ratio	0.0488	0.0408	0.09	(0.1235)	(0.0637)
Catch/set	0.02	0.65	9.61	(0.03)	(2.28)
Disc/set	0.00	0.03	0.86	(0.00)	(0.14)
<u>All Tunas</u>					
Discard/ catch ratio	0.011	0.0442	0.1667	(0.0224)	(0.0721)
Catch/set	17.80	15.28	39.84	(17.00)	(30.05)
Disc/set	0.20	0.68	6.64	(0.380)	(2.167)

The incidental mortality of dolphins in the EPO tuna purse seine fishery, which was unsustainable in the early years, has been reduced by 97% over the last decade. This shows that it is possible to continue the utilization of resources in a way which is more ecologically sound, but solutions are not easy to find, are not cheap, and when they affect resources that cross political boundaries they require a commitment of the international community to succeed. The coming decade should see a concerted international effort to mitigate the ecological impacts of fishing operations. Purse seines and gillnets produce a large proportion of the world fish catches for both industrialized and developing countries and, lacking better alternatives, it is unlikely that they will disappear any time soon. The mitigation efforts should include mounting a major research and development program with the short-term objective of generating improvements of the gear and techniques used that would allow more selective fishing (reducing unwanted captures, increasing live release of captured individuals, or increasing utilization), and the long-term objective of finding alternative ways of fishing.

Literature Cited

Alverson, D.L., Freeberg, M.H., Pope, J.G. and Murawski, S.A. (1994). A global assessment of

fisheries bycatch and discards. FAO, Fish.Tech.Paper No.339. Rome, FAO, 233 p.
Bailey, K., Williams, P.G., and Itano, D. 1996. By-catch and discards in Western Pacific tuna fisheries: a review of SPC data holdings and literature. South Pacific Commission, Oceanic Fisheries Program Tech. Rept. No.34. Noumea, New Caledonia.
Cayre, P., Amon Kothias, J.B., Diouf, T. and J.M. Stretta. 1988. Chapter 6: Biologie des thons, p.157-268. In A. Fonteneau and J. Marcille (eds.) Ressources, peche et biologie des thonide's tropicaux de l'Atlantique Centre-Est. FAO, Doc.Tech.sur les Peches, No.292.
Coffey, B.T. and Grace, R.V. 1990. A preliminary assessment of the impacts of driftnet fishing on oceanic organisms: Tasman Sea, South Pacific, January 1990. Brian T. Coffey and Associates, Ltd.: E.I.A./S.D.F. (G.P. 01/1990). 19p. (MS)
Dayaratne, P. and de Silva, J. 1990. Drift gulnet fishery in Sri Lanka. Indo-Pacific Tuna Development and Management Programme. Coil. Vol. Working Doc. Vol.4:230-234.
Dolar, M.L.L. 1994. Incidental takes of small cetaceans in fisheries in Palawan, Central Visayas and Northern Mindanao in the Philippines. In "Gulnets and cetaceans," Perrin, W.F., Donovan, G.P., and Barlow, J. (eds.) Rep. mt. Whal. Commn. Spec. Issue 15:355-363.
Felix, F. and Samaniego, J. 1994. Incidental catches of small cetaceans in the artisanal fisheries of Ecuador. In "Gulnets and cetaceans," Perrin, W. F., Donovan, G.P., and Barlow, J. (eds.) Rep. mt. Whal. Commn. Spec. Issue 15:475-480.
Francis, R.C., Awbrey, F.T., Goudey, C.L., Hall, M.A., King, D.M., Medina, H., Norris, K.S., Orbach, M.K., Payne, R., and Pikitch, E. 1992. Dolphins and the Tuna Industry. National Academy Press, Washington, D,C,: xii, 176 pp.
Goujon, M. 1996. Captures accidentelles du filet maillant derivant et dynamique des populations de dauphins au large du golfe de Gascogne. Les Publ. Du Lab. Haheutique No.15. Ecole Nationale Supeneure Agronomique de Rennes. Thesis. 239 p.
Hall, M.A.1996. On bycatch. Reviews in Fish Biology and Fisheries 6:319-352. Harwood, M.B. and Hembree, D. 1987. Incidental catch of small cetaceans in the offshore gulnet fishery in Northern Australian waters: 1981-1985. Rep. mt. Whal. Commn. 37:363-367.
Harwood, M.B., McNamara, K.J, and Anderson, G.R.V. 1984. Incidental catch of small cetaceans in a gulnet fishery in Northern Australian waters. Rep. mt. Whal. Commn. 34:555-559.
Joseph, J. 1994. The tuna-dolphin controversy in the eastern Pacific Ocean: biological, economic and political impacts. Ocean Development and International Law, 25:1-30.
Lablache, G. And Karpinski, B. 1988. Seychelles research observer program. Indo-Pacific Tuna Development and Management Project, FAO. Coil. Vol. Working Doc., Vol. 3:146-153.TWS//88/53.
Leatherwood, S. and Reeves, R.R. 1989. Marine mammal research and conservation in Sri Lanka 1985-1986. UNEP Mar. Mammal Tech. Rep.
Leatherwood, S. 1994. Re-estimation of incidental cetacean catches in Sri Lanka. In "Gulnets and cetaceans," Perrin, W.F., Donovan, G.P., and Barlow, J. (eds.) Rep. mt. Whal. Commn. Spec. Issue 15, Report of the Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps, Annex D p.64-65,1990, La Jolla, California.
Lennert, C. and Hall, M.A. 1995. Estimates of incidental mortality of dolphins in the eastern Pacific Ocean tuna fishery in 1993. Rep. mt. Whal. Commn. 45: submitted.
Medina-Gaertner, M. and Gaertner, D. 1991. Factores ambientales y pesca atunera de superficie en el Mar Caribe. ICCAT, Coil. Vol. Sci. Papers, Vol.36:523-536.
Northridge, 5. P.1991. Driftnet fisheries and their impacts on non-target species: a worldwide review. FAO Fish. Tech. Paper 320,115 pp.
Pacific Tuna Development Foundation. 1977. Final Report Tuna purse-seine charter to the Western Pacific. July-November 1976.
Reyes, J.C. and Oporto, J.A. 1994. Gillnet fisheries and cetaceans in the southeast Pacific. In "Gulnets and cetaceans," Perrin, W.F., Donovan, G.P., and Barlow, J. (eds.) Rep. mt. Whal. Commn. Spec. Issue 15:467-474
Sabadach, B., and Hallier, J.P. 1993. Analyse des donnees collectees lors des embarquements a' bord des senneurs base's aux Seychelles (1986-1991). Seychelles Fishing Authority, SFNR&D/024.
Sharples, P., Bailey, K., Williams, P., and Allan, A. 1990. Report of observer activity on board JAMARC driftnet vessel R.V. *Shinhoyo Maru* fishing for albacore in the South Pacific Ocean. Working Paper No.3, Third South Pacific Albacore Res. Workshop, Noumea, New Caledonia, 9-12 October, 1990.
Van Waerebeek, and Reyes, J.C. 1994. Post-ban small cetacean takes off Peru: a review. In "Gulnets and cetaceans," Perrin, W.F., Donovan, G.P., and Barlow, J. (eds.) Rep. mt. Whal. Commn. Spec. Issue 15:503-520.

Williams, P.G. 1996. An update on by-catch issues in western and central Pacific Ocean tuna fisheries. Asia-Pacific Fishery Commission (APFIC) Symposium on Environmental Aspects of Responsible Fisheries. Seoul, South Korea. October 15-18,1996.

Martin A. Hall received the degree of Licenciado in biology from the University of Buenos Aires in 1972. In 1977 he received a Fulbright Fellowship to study fisheries at the University of Washington, from which he obtained his Ph.D. in 1983. In 1984 he was hired by the Inter-American Tropical Tuna Commission and put in charge of its Tuna-Dolphin Program. At the Commission he has done research on the estimation of dolphin mortality and its statistical problems, and on the association of tunas with floating objects. Currently he is working on the ecological impacts of fisheries, especially bycatch, with the long-term objective of understanding the effects on the ecosystem of current harvesting techniques and the short-term goal of devising strategies to mitigate those impacts.

Peter G. Williams is employed by the South Pacific Commission in Noumea, New Caledonia.

GETTING AHEAD OF THE CURVE

CONSERVING THE PACIFIC OCEAN'S TUNAS, SWORDFISH, BILLFISHES AND SHARKS

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TABLE OF CONTENTS

LIST OF SPECIES

Common Name	*Scientific Name*
Southern Bluefin Tuna	*Thunnus maccoyii*
Skipjack Tuna	*Katsuwonus pelamis*
Yellowfin Tuna	*Thunnus albacares*
Bigeye Tuna	*Thunnus obesus*
Black Skipjack Tuna	*Euthynnus lineatus*
Northern Bluefin Tuna	*Thunnus thynnus*
Albacore Tuna	*Thunnus alalunga*
Longtail Tuna	*Thunnus Tonggol*
Little Tunny	*Euthynnus alletteratus*
Kawakawa	*Euthynnus affinis*
California Bluefin	*Thunnus saliens*
Broadbill Swordfish	*Xiphias gladius*
Black Marlin	*Makaira indica*
Blue Marlin	*Makaira nigricans*
Striped Marlin	*Tetrapturus audax*
Sailfish	*Istiophorus platypterus*
Shortbill Spearfish	*Tetrapturus angustirostris*
Blue Shark	*Prionace glauca*
Oceanic Whitetip Shark	*Carcharhinus longimanus*
Silky Shark	*Carcharhinus falciformis*
Shortfin Mako Shark	*Isurus Oxyrinchus*
Thresher Shark	*Alopias spp.*
Porbeagle Shark	*Lamna spp.*
Soupfin Shark	*Galeorhinus galeus*
Spotted Dolphin	*Stenella attenuata*
Spinner Dolphin	*Stenella longirostris*
Common Dolphin	*Delphinus delphis*
Frigate and/or Bullet Tuna	*Auxis spp.*
Sierra	*Scomberomorus sierra*