International fisheries management toward responsible fisheries：

Negative impacts in capture fisheries: bycatch and discards and derelict fishing gear and ghost fishing

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I. CODE OF CONDUCT FOR RESPONSIBLE FISHERIES

The Code of Conduct for Responsible Fisheries was endorsed at FAO and published in 1995. It is recognised as a strategic guideline for fisheries management and lists negative aspects to be solved in capture fisheries, *e.g.* bycatch and discards, fishing gear loss and ghost fishing, destruction of habitats, less selective fishing practices, *etc*. Discards and ghost fishing by derelict fishing gear are the most seriously and direct negative impacts to the aquatic resources caused by fishing activities. These are also important issues in resource biology. Unaccounted mortality is recognised nowadays, which is not negligible in comparison to the accounted fishing mortality. It is required to access the mortality due to both phenomena and examine the problems in fishing practices to clarify if those mortalities are truly serious problems and, if so, to find solutions,

II. BYCATCH AND DISCARD ISSUE

Discarding bycatch became concerned as the single most serious wastage in capture fisheries against rational utilisation of resources during the 1970’s. It became an international issue in fisheries management since the estimation of global discards by FAO Technical Paper 339 and adoption of FAO Code of Conduct for Responsible Fisheries.

The bycatch issue involves those of both fisheries organisms, such as finfishes, crustaceans *etc.* and those not aimed in fishing, such as marine mammals, marine reptiles and seabirds. The latter is referred to as an incidental catch. Two groups of animals have different characters both in implications in the fisheries management and from the viewpoint of the required technology toward solutions, therefore, it is difficult to deal in one context. This paper deals with the bycatch and discards of mainly fisheries organisms.

1. Definition of terms

A catch is defined as those hauled up onto deck by fishing gear. They are retained in part, while the others, discarded. A retention and landing are almost synonymous in industrial fisheries, however, self-consumptions in retention is not negligible in small-scale fisheries. The definition of discards is almost consensus, however, there are still different views such that release in sport fishing and safe returning to the sea after friendly sorting onboard are excluded.

A bycatch is hardly defined scientifically. The meaning of bycatch is different among countries and among researchers. Alverson used a concept of a set of target catch and bycatch, however, this concept is hardly applicable to multi-species fisheries prevailing over Asia and tropical waters. This paper temporality defines as bycatch is the irrational catch other than the catch of species, sizes and sex acceptable in resource conservation and management.

2. Estimation of discard amounts

A total of 5 million tons of annual discards in the world prawn trawl fishery was estimated on the basis of the discard ratios against the catch of prawns, usually 5 to 10, which were multiplied by a total production of prawns. This method was applicable because the anticipated prawns and unwanted finfishes as bycatch are distinctive in this sector. The estimation of discards in later researches was unconsciously affected by this method.

FAO Fisheries Technical Paper 339 estimated 27 million tons of global discards annually. Though discard estimates by country were concealed, it was presented that 47% of the global discards occurred in Asia, in particular, 9.13 million tons in Region-61, or Northwest Pacific, which was unrealistically large. An expert consultation meeting convened by FAO revealed that Paper 339 had a methodological weakness which did not take the landings as non-target catches into account and fell into over-estimation of discards. A revised estimation of global discards of 6.8 million tons was publicised by FAO recently. This report includes unacceptably unnatural assessments, *e.g.* the discard amount estimated for Korea is the smallest in Asia and less than that by North Korea. There is still no reliable estimation of global discards even nowadays.

There are several reasons of the confusion in discard estimation. One is the fuddled definitions of bycatch and discards as explained above and the other, less logical approach to the estimation methodology. In order for discard estimation, a discard ratio r in a fishing sector is found from a field survey as Equation (1) where d_k and c_k are discard and landing amounts at the k-th in K times sampling. The total amount of discards D in the concerned sector is estimated as Equation (2), with the total amount of landing C in the sector, which is usually available in landing statistics. However, a variety of discard ratios are definable with the landing amount of either summed species, target species, or an individual species as a denominator. In application of the Equation (2), a discard ratio must be multiplied only by the corresponding landing amount.

$$r = \frac{1}{K}\sum_{k=1}^{K}\frac{d_k}{c_k} \qquad \cdots\cdots (1)$$

$$D = r \cdot C \qquad \cdots\cdots (2)$$

Matsuoka proposed that a discard estimation method with the discard ratio against summed species in each sector is the best in order to avoid the confusion. Another method based on 'discards per unit effort' (DPUE) q is also possible.

3. True problems of bycatch and discards

Despite the prevailing concerns to bycatch and discards with emotional warning sometime, it is not clearly understood what are real problems. Most concerns have been raised from a viewpoint of protection of wild life and management of resources as below. Bycatch includes endangered or protected species or juveniles of commercially important species sometime. Discarding juveniles of highly commercial species due to landing size regulations undermines the principal purpose of fishing regulations. There are many suggestions which indicate that mortality by discards may provoke negative impacts to aquatic ecosystems and biodiversity, consequently, discards of even non-utilised species are unacceptable. Discards of species which are aimed in other fishing sectors causes conflictions. In developing countries, bycatch and discards by industrial fisheries to the species utilised in subsistent fishing by nearby villagers arise a problem against a national development policy such as conservation of the basis for rural life.

There is an essential subject if discarded organisms cannot survive, because all the above criticisms are based on a presumption of mortality of discards. Experiments following the first experiment on this issue conducted in the prawn trawl fishery in Gulf of Carpentaria are generalised as the mortality of discarded small fishes and those with gas bladders is high, while survival is high for large finfishes and crustaceans. Survival also depends on the fishing depth, sorting time on deck and deck conditions such as temperature, wetness *etc*.

There are counter disputes as bycatch and discards are not problems, *e.g.* (1) bycatch reduces predators to juveniles of high-value species and contribute to human utilisation of resources, (2) discards of demersal species contribute to vertical circulation of nutrients and enhance the productivity of fishing grounds, and (3) flat mortality to all the species is rather friendly to ecosystem. These criticisms encourage researches on the consequences of discards recently.

Brewer first analysed stomach contents of bycatch finfishes by prawn trawlers in Gulf of Carpentaria and proved that they eat small non-commercial shrimp species. Mortality of small finfishes reduces the predation pressure to shrimps other than commercial prawn species. This does not support the above hypothesis (1).

The energy flow from discards to subsequent consumption by organisms, including externalisation from aquatic environment is one of the largest research subjects currently. An investigation on the probable fate of discards from prawn trawlers found that most discards sink, where the majority are scavenged on the seabed. On the other hand, floating fish was consumed by seabirds and externalised. These suggest that discards could not enrich surface waters in nutrients and refuse the hypothesis (2).

Bycatch finfish compositions were compared between before the start of prawn trawl industry and 20 years later in the Gulf of Carpentaria and it was found that species such as ponyfishes distinctively declined. This result suggests that the impacts of bycatch and discards are different among species and denies the hypothesis (3). Regardless this analysis, an assumption that bycatch induces flat mortality to all the organisms in an ecosystem is far from a reality, because of the biased catch by selectivity of fishing gear.

It is pointed as discarding is not a problem as long as landing is increased. It suggests that the bycatch and discard issue is a matter how to utilise the resources in a fishing ground and maximisation of allowable catch is the final goal. It must be carefully studied if partial reduction from population by bycatch mortality increases the MSY of commercial species.

4. Solutions to bycatch and discards

Bycatch is attributed to weak selectivity of fishing gear and multi-species characters of fishing grounds, while discards are attributable to less profitability. Possibility of discards is high where the price difference is large between wanted species and others. Discards due to genuine non-edibility are peripheral. Some discards occur due to landing size regulations. The insufficient space of fish holds on fishing vessels is mentioned as a reason, however, this is a synonymous of vessel designing with precondition of bycatch.

There have been two ways of approaches toward countermeasures against bycatch and discards as; (1) underwater exclusion of unwanted species and (2) utilisation of bycatch.

Improvement in fishing technology: There are two directions in fishing technology toward reduction of unwanted catch; (1a) improvement of fishing gear design and (1b) development of bycatch exclusion devices to be added to fishing gear.

The typical approach in the former direction is the conventional mesh-size regulation to exclude small individuals of fishes to be discarded otherwise. Using square-mesh panels is one of the typical ways for activation of size selectivity by opening meshes widely. The latest achievement is that discards can be reduced by around 40% through application of square-mesh panels to trawl gear. Starting researches on species selectivity over the world in the 1990’s must be the reflection of the bycatch and discard issue. Even marginal modifications such as changing vertical opening and foot-gear arrangement for trawl and underwater height and spaces around a foot rope for gillnets result in altering the species selectivity. There are still extensive possibilities to exclude unwanted species and sizes by selectivity for most fishing gear.

Development of bycatch reduction devices is advanced in trawl. Devices referred to as TED (Trawl Efficiency Device), BED (Bycatch Exclusion Device) and BRD (Bycatch Reduction Device) have been developed particularly for prawn trawling. This is attributable to that exclusion of small bycatch finfishes by mesh size regulation is difficult, because of the similar sizes between prawns and bycatch finfishes in prawn trawl. Most bycatch reduction devices for trawl nets are composed of net-webbing/grids and open sections such as windows or large-meshed skylight. The function of the former is an induced exclusion by mechanical size-selectivity and the latter, passive exclusion based on difference in behaviour amongst animals.

One of the reasons of relatively low exclusion ratios for exclusion devices is that the chances for organisms to encounter with their grids or meshes are limited because they are usually short longitudinally. Given the probability to pass through a grid or mesh space at once encounter for an individual animal of size *L* as *f* (*L*), the probability of remaining after encountering for *n* times is described as Equation (3).

$$S(L) = (1 - f(L))^n \qquad \cdots\cdots (3)$$

S(*L*) is the selectivity. The S(*L*) curve becomes steeper with increasing *n*. In other words, encounter for as many times as possible is needed to exclude small individuals.

Code of Conduct for Responsible Fisheries repeatedly urges improvement of survivability for excluded escapees. However, low survivability for Baltic herring excluded from a trawl codend has been reported and suggested that the codend mesh size management must be reconsidered.

There are trials of technical development towards friendly release of bycatch organisms, *e.g.* release after sorting in a shallow tank on deck or under a shower. There is, however, a criticism that the survival possibility for the released individuals are not very high, *e.g.* chances to return to the original habitat and participate into reproduction may be limited, in particular, in the case of deep water species. Segregation between friendly release and discarding is also questionable.

For further development of bycatch exclusion devices, the technology must give more consideration to merits for fishers to compensate the possible loss of catches, *e.g.* reduction of resistance to a net and consequent fuel consumption, reduction of on-deck work, and improvement of quality of catches. Reduction of fishing gear materials is also a possible merit.

Promotion of landing: It is said that there is no problem as long as catches are utilised. The officials and researchers from some Asian countries rely upon this logic and insist that there is no discard problem in the region, because of landing of small finfishes as so-called trash fish. It is truism that catches are all utilised in many countries in this region, however, there is an essential problem that trash fish usually includes juveniles of commercially important species. Careless promotion of landing may undermine the principle to avoid catching juveniles in fisheries management. No discard is not necessarily a synonymous of rational utilisation.

Landing of bycatch is usually promoted with public investment, *e.g.* often conducted as official development assistance (ODA) projects. The author observed an ODA project, where fishing companies became able to sell finfishes discarded otherwise due to establishment of a marketing system. No additional investment was needed for fishing companies themselves and newly born commercial value of those species shifted the cost and income balance. It resulted in increased fishing effort and, consequently, the resource condition of wanted species declined.

Researches on sensory and behaviour: Researches on the capture processes are the basis for development of selective fishing, and sensory and behaviour of aquatic organisms have been studied for this purpose. For example, the difference in swimming ability between prawns and finfishes and the difference between optomotor reaction by finfishes and reflex response by prawns in a trawl net are the ruling factor in separation. The author considers that guidance of animals by utilising visual responses, including the optomotor reaction is the key in designing bycatch exclusion devices, *i.e.* incontinuity in the net structure and material colour, including windows and large-mesh sky-light, *etc.* of TED is the stimulation to induce reactions to result in exclusion of unwanted animals. Passive exclusion relying upon behavioural differences is applicable even when the size difference is small between wanted and unwanted species. Utilisation of a difference in swimming layer must be the most effective way in development of species-selective gillnets. In addition to the visual sensory, there are many researches on hearing, taste, chemical, tactile and lateral line sensory. The researches in this orientation are important also toward the exclusion of incidental catches of sea turtles and sharks, beyond the mechanical selectivity of fishing gear.

III. GHOST FISHING BY DERELICT FISHING GEAR

Ghost fishing implies that derelict fishing gear left the fisher’s control no matter intentionally or accidentally remains its capture function in water and continues inducing mortality of fishery organisms. It was recognised in the 1960’s and scientific studies started in the 1970’s. It became an influential issue as the closure of the high-seas drift net fishery in the late 1980’s was justified, in part, with the possibility of ghost fishing. The process of the ghost fishing undergoes entirely underwater and none is observed in ambient in usual fishing practices. A number of intellectual researches have been conducted and the reality of ghost fishing is becoming evident recently.

1. Influences by derelict fishing gear and ghost fishing

The direct influences by derelict fishing gear to organisms include ghost fishing and incidental catch of wild lives such as marine mammals, marine reptiles and sea birds. Indirect ones are accumulation of derelict gear on seabed and coral reef, contamination on beaches and deformation of seabed. There should be indirect mortality bridged by declining environment.

1.1 Mechanisms of ghost fishing

Consequences after gear loss were not concerned before the introduction of synthetic materials for fisheries in the 1960's. Ghost fishing by derelict fishing gear were thought to have started by use of non-degradable fibres to fishing gear. Ghost fishing is, however, serious immediately after gear loss. Even fishing gear made of natural materials was not free from the problem. It is beyond a fact to describe that ghost fishing is a new problem since the introduction of synthetic fibres.

The truism of ghost fishing was questioned for a long time. Fishing gear remaining in the sea or entrapment of animals is not an adequate evidence to prove it. Ghost fishing is only proved with dead bodies of animals. It has been confirmed only in traps such as pots (cage-type traps) and tubes, gillnets, trammel-nets and small seine nets made of net webbing similar to that of gillnets.

After finding the evidences of mortality, researches were oriented towards those on the process to induce ghost fishing.

Pots (cage traps) and tubes: Underwater observation of lost pots in a coastal water in Japan observed many organisms in the pots remaining the original structures, while fewer organisms in pots largely deformed due to breakage of frames, burial in sediment and accumulation of fouling organisms. Aged pots heavily covered by algae and fouling organisms were almost empty even though functional. The organisms confined in a pot demonstrate a variety of unusual behaviour, *e.g.* bumping on webbing inside, occasional rolling *etc.*, which they never show in the natural environment. It is a hypothesis that the unusual behaviour is attributed to the high density and consequent stress in the animals which seldom meet in the natural fauna. The mortality induced by unusual behaviour and subsequent injury was clearly indicated by their correlations. The contents of the digestion organs of entrapped fishes were analysed and few empty ones were found. This proves that starvation is not a reason of ghost fishing mortality in a pot.

Long-term observation indicated that the ghost fishing function descends together with breakage and accumulation of fouling organisms. The former must be strengthened by the wave excitation force around the seabed and the latter, the high productivity and rich fauna in shallow waters. Therefore, the capture function of deep-water pots which are less damaged by waves and less fouled biologically may continue ghost fishing for a longer period of time.

Ghost fishing by tubes for conger eel and hagfish has been evidenced in the Sea of Japan recently. Because of the structure of the entrance, all the entrapped fishes are conjectured to be killed, while those which lost an entrance funnel maintain no more capture function. The rate of removal of the entrance funnel has not clarified yet.

Derelict traps, together with gillnets, are self-baited with dead bodies of ghost-fished animals and this may accelerate and prolong ghost fishing for finfishes. On the other hand, dead bodies of crustaceans in a pot may decelerate entries and subsequent mortality of the same species.

Gillnets and trammel-nets: Ghost fishing mortality by bottom gillnetscontinues for a relatively short period of time. Consequences for derelict gillnets are affected by seabed conditions. The ghost-fishing function of gillnets on the flat seabed declines rapidly with decreasing heights and increasing visibility. Decline in height is mainly attributable to enmeshed algal fragments and debris, subsequent increase of weight and hydrodynamic resistance and gradual sticking around seabed. It is noted that the duration of ghost fishing is different from species to species, hence, the main ghost-fished species seem to be replaced through the time course, as sub-demersal swimmers are caught in the first several days and seabed dwellers, for a longer period of time.

Gillnets vertically stretched over an underwater structure, such as FAD and wreck maintain the initial magnitude of ghost fishing for a much longer time. A gillnet experimentally tangled around an artificial reef and left for longer than 3 years showed no decline in ghost fishing, even after so badly fouled as the netting monofilament was no longer visible. Ghost fishing of crabs and lobsters by badly damaged gillnets and even their fragments is frequently observed. This suggests that ghost fishing of crustaceans by gillnets may continue longer than finfishes.

Other types of fishing gear: Ghost fishing mortality appears in small seine nets composed of thin-twine webbing which is usually used for gillnets. Small boat and beach seine nets as such are frequently observed in developing countries where an available variation of net webbing is limited.

1.2 Other issues by derelict fishing gear

Aggregation of a large number of fish by an artificial reef covered by net webbing was observed. This shows enhancement of FAD's function, however, the numbers of individuals of the species for which ghost fishing mortality was recorded did not increase. This phenomenon may indicate such a serious problem as those species are aggregated and killed by ghost fishing.

It is empirically true that derelict fishing gear itself has a micro-FAD effect to aggregate fishes. This is not inevitably positive. The fish community newly formed around derelict fishing gear is different from the natural ones in the vicinity. There may be a new prey-predator relationship.

Ceramic octopus pots remaining underwater do not cause mortality of animals obviously and they are dwelled and utilised even for spawning by a variety of organisms. Large fishing gear, such as trawl nets and sank aquaculture cages made of thick and rigid materials form a large number of small compartments, which likely support spawning and protect juveniles.

The problems of accumulation of fishing gear and their parts on seabed, entanglement on coral reefs and contamination on beaches are publicised. The concern assumes that non-degradable foreign materials may cause declining the environment. The author observed deformation of seabed, where spaces around rocks covered by lost nets are buried with sediment and changed to flat bottoms. A hypothesis is if the local flow around a net is decelerated due to fouling organisms on meshes, and consequently, deposition occurs. This process simplifies the seabed topography and may reduce biodiversity. This is also the process of burial of lost fishing gear in sediment and termination of ghost fishing. It is yet unknown if this process is irreversible or not.

Derelict fishing gear drifts and are widely spread over the ocean, which is referred to as marine debris. Foreign-origin trawl nets are piled up in Pacific islands and those entangled on coral reefs are hardly retrieved due to possible destruction of corals. These cause irreversible destruction of marine environment and magnify the entanglement of marine mammals. Derelict gear which are swept away from the original fishing grounds and damage the other areas provoke external conflicts either internationally or domestically. Although their origins are identified usually on the basis of the prints, marks *etc.* on the materials, their identification is not simple because the origin of materials is not necessarily that of fishing gear.

The possibility of navigation hazard is also concerned. Derelict fishing gear drifting at surface may be tangled around a propeller and a rudder of vessels.

2. Quantitative information related to ghost fishing

Death rate: The rate of death to animals entrapped in a pot has been found as from 7% to 100%. The reported rates may, however, stand for those immediately after gear loss, because most experiments to find a death rate were conducted with test animals which were initially put in a pot by researchers for subsequent monitoring. There is no report on the death rate for gillnets perhaps because entire kill of the enmeshed population is assumed.

Duration of ghost fishing: Finfish pots even in a shallow-water continue ghost fishing for as long as three years sometime and catch of crustaceans by pots continue longer. The author found the ghost fishing by a coastal finfish pot continued for 690~1,030 days.

Kaiser *et al.*, Erzini *et al.* and Nakashima and Matsuoka formulated the descending trend in mortality since loss for bottom gillnets on the flat seabed. The duration of ghost fishing was assessed as 56~142 days. However, level off of the ghost fishing function at approximately 20% of the original catch efficiency and no decline of mortality have been also reported. Gillnets tangled around an FAD maintained almost the original catch rate even after three years.

Mortality per gear: The above-listed researches also indicated the mortality by gillnets of

318~455 animals per net. A mortality by trammelnets was estimated as around 78 and 754. That by a side entrance pot was estimated as 315 individuals including 98 octopuses.

Mortality in fishing sector: This is usually indicated as a ration of ghost fishing mortality in comparison to the landing amount in the same fishing sector. The mortality ratios have been reported as; 7% for Dungeness crab in a pot fishery in Fraser River Estuary in Canada, equivalent to or two times more for octopus in a pot fishery in a coastal fishing ground in a municipality in Kagoshima, Japan, 7% for monkfish in a gillnet fishery in Cantabrian Sea in Spain, and 0.5% for hake in a gillnet fishery in Algarve in Portugal. The economic loss due to ghost fishing by derelict pots in Kuwait was reported to be equivalent to 3-13.5% of the value of landing.

3. Model for mortality estimation

The author developed a simple model for a large-scale estimation of ghost fishing mortality in a fishing sector. Ghost-fishing mortality, F_g of a species or a group of animals in a fishing sector over a unit period of time, *e.g.* a year, is denoted as;

$$F_g = E_d \cdot m \qquad \ldots\ldots (1)$$

where E_d is the number of fishing gear loss in a sector in a unit time period and *m*, the ghost fishing mortality per gear during a period of time until the ghost fishing function ceases. This model is comparable to that popular in fisheries science to describe fishing mortality with devoted fishing effort and CPUE and has an advantage where some data are obtainable on land.

Micro-assessment: The author proposed a concept of Ghost Fishing per Unit Effort (GPUE) to *m*. The *m* is assessed statistically on the basis of monitoring dead animals in fishing gear underwater. The survival function is applied to represent the declining trend, where the function descends with a decline rate *b* from the initial value *a* with the elapsed days, *t* since gear loss as;

$$N_m(t) = a \cdot (1 - b)^t \qquad \ldots.. (2)$$

An integral of the equation of $N_m(t)$ such as (2) from $t = 0$ to T_{max} or the point in time of termination of ghost fishing gives the accumulated ghost fishing mortality, *m* per gear.

$$m = \int_{t=0}^{T_{max}} Nm(t)\, dt \qquad \ldots.. (4)$$

Because the survival equation does not cease to 0, $T_{0.05}$ is defined as the equation value becomes 5% to the value when $t = 0$, in order to approximate $T_{\max}$.

Macro-assessment: The number of fishing gear loss a year in a sector E_d is estimated as;

$$E_d = N_f \cdot r_o \cdot N_g \cdot r_l \qquad \ldots\ldots (5)$$

where N_f is the number of registered fishing unit, or fishers or fishing vessels, r_o is the ratio of the units actually operating among N_f, N_g is the average number of fishing gear used by individual fishing units, and r_l is the average ratio of the annual gear loss among N_g.

The annual gear loss rates (annual turn-over rates) r_l is the most important parameter for assessment of ghost fishing in a sector. The author's survey in coastal fisheries in Kyushu, Japan found the values as 0.05 to 0.16 in bottom gillnet and 0.05 to 0.12 in pot fisheries. Such values as 1 or more were obtained in the Caribbean allow-head pot fishery, 0.2 in crab pot fishery in the Sea of Japan, and 0.2 in coastal finfish pot fishery in Kyushu Japan have been obtained.

4. Development of countermeasures

Countermeasures to solve ghost fishing are in two directions as; (1) before fishing gear loss such as prevention of gear loss, (2) after gear loss as retrieval or dysfunction of lost gear.

Prevention of fishing gear loss: The reasons for fishing gear loss are mainly; (1) entanglement of gear or its accessory parts around seabed to unable hauling, (2) cut of a float line and dislocation due to interaction with other fishing gear, (3) misplacement during operations, and (4) drop of fishing gear either accidentally or intentionally.

Entangling of fishing gear around bottom rocks are avoidable in a certain extent by technical improvement, *e.g.* an intermediate float for bottom-set fishing gear. The true reason of gear loss due to entanglement is, however, some fishers' behavior that precarious grounds are fished, taking a risk of potential gear loss into account, where fishing gear is relatively inexpensive. Public awareness of the long-term impacts to resources by ghost fishing is, therefore, the essential approach in this aspect.

Small fishing gear is destructed by larger gear, where multiple types of fishing gear are used in the same fishing ground, *e.g.* float lines of small bottom-set gear are broken by larger drag-net operations and mooring ropes of aquaculture cages. Rationalised management of multi-sector fishing in a coastal fishing ground is important.

The possibilities of the categories (3) and (4) above may be marginal for fishers equipped with new position-fixing devices such as GPS. Submerged markers are, however, widely used in some developing countries to avoid theft and predictably misplaced. Therefore, promotion of moral and social welfare is important particularly in deprived communities toward proper fishing.

Retrieval or dysfunction of lost fishing gear: Iron clasps are widely used for retrieval of lost gear, however, it is suspected if further damages to the seabed may be provoked. Voluntary cleaning of seabed and dysfunctioning of lost gear is educationally effective, however, hardly a practical and essential solution due to low efficiency and limited applicability in shallow waters.

Designed degradation of fishing gear: Designed degradation of gear parts have been tested, *e.g.* for the time-sensitive releasable escape gap to a pot which opens after immersion for a certain period of time. This technique is already practically applied in fishing regulations. This is particularly successful for pots because the ghost fishing function of pots continues for a long period of time with slow declining and, therefore, technically allowable time is long enough to control the period for degradation of parts. Usage of degradable materials for gillnets must be carefully considered, taking into account that ghost fishing by gillnets is the most serious immediately after gear loss, *e.g.* only within a couple of days for some species. It is not realistic to satisfy both intended degradation and required durability for fishing gear materials.

Prevention of economic loss: The most important but less studied area is legislative countermeasure to avoid fishing gear loss. Fishing gear loss is an economic loss against business viability for fishers and sustainability of capture fisheries. Countermeasures after gear loss are, therefore, alternatives and prevention of fishing gear loss is the most fundamental countermeasure.

IV. Conclusions

Although the overall impacts by discards and ghost fishing have not been clarified yet, the challenge to assess and to reduce the problem must secure the future of the capture fishery because the resources currently wasted by these phenomena are convertible to new resources additional to human utilisation. As encouraged by FAO as early as in the 1980's, conversions from discards to landing and ghost-fishing mortality to catches are comparable to finding new resources. The author wishes to urge that researches on these issues will open a new horizon toward responsible capture fisheries and it is the synonymous of finding of new food resources for human being.

ABSTRACT

This lecture mainly deals with bycatch/discard and ghost fishing which are listed as adverse fishing practices in the Code of Conduct for Responsible Fisheries. The history of bycatch and discard issue, including the technical terms, global discards, methodology of estimation of discard amount are reviewed. The true problems of bycatch and discards, approaches toward technical solutions, including improvement in fishing technology and needs of researches on sensory and behaviour are discussed. A total of 27 million tons and a revised value of 6.8 million tons of global discards have been estimated, however, there is still no reliable discard estimation globally. Ghost fishing implies that derelict fishing gear remains its capture function in water and continues inducing mortality of fishery organisms. Influences by derelict fishing gear and ghost fishing are reviewed. The mechanism of ghost fishing mainly for pots and gillnets and other issues provoked

by derelict fishing gear are listed. Quantitative information related to ghost fishing such as death rate, duration of ghost fishing, mortality per gear and mortality in fishing sector are reviewed and a model for ghost-fishing mortality estimation is proposed. Development of countermeasures and importance of prevention of fishing gear loss is explained.

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