collection of such information to ensure that the species and their habitats would not be impacted by fishing activities, and on the development and management of the coastal and marine resources.

Developing aquaculture technologies to reduce pressure on species under international concern

- Relevant institutions should consider developing technologies for aquaculture of species under international concern, *e.g.* seahorses, sea cucumbers, anguillid eels, with a view to reducing the threats from fishing to the natural population of the species.

Enabling trade of aquatic species under international concern

- Relevant organizations should provide capacity building on the development of documents required for the trade of fish and fishery products, *e.g.* NDF document for the trade of species listed under the CITES Appendices, or other documentary evidence showing that the harvest of certain fish and fishery products are conducted in a way that no harm was created to the specific species that are subject to the trade-related regulations.

4. Responsible Fishing Practices

4.1 Status, Issues, and Concerns

4.1.1 Reduction of Impacts of Fishing on the Environment

The conduct of fishing activities can create impacts not only on the targeted species and resources but also on the other resources associated with the existence of the dependent species. These include the benthic communities at the bottom of the oceans where bottom-towed fishing gear is operated to target the pelagic resources. Moreover, endangered, threatened, and protected (ETP) aquatic species including sea turtles and marine mammals could also be impacted by fishing gear being operated at the surface and sub-surface water columns. Since the 1990s, several regional studies had been undertaken by researchers to determine the impacts on the resources, of fishing activities that catch juveniles or non-target species and bring about bycatch and discards. Fishing activities could also result in degradation of the environment and habitats due to the very nature of the fishing techniques used, *e.g.* use of dynamite or poison, or the inappropriate use of otherwise acceptable gear, *e.g.* using trawls in coral reefs or seagrass beds.

Impacts of Fishing on the Fishery Resources

Fishing activities can have direct and indirect impacts on the abundance and spawning potentials of the fishery resources, and possibly on population parameters, *e.g.* growth, maturation, among others. Fishing could also modify the structure of fish populations, such as size, sex ratio, species composition, not only of the target species or resources but also of their associated and dependent species, as well as other ETP species living in the ecosystems. FAO (2010a) described the impacts of fishing on biodiversity, which could occur in the following forms: (i) modification of community structure, *e.g.* trophic structure; (ii) reduction in species richness or other taxonomic diversity indices; and (iii) risk of local extinction, *i.e.* severe reduction of the impacted populations to the extent of becoming threatened, endangered, or even locally extinct.

The negative impacts of fishing activities on the fishery resources could occur in all fishing practices without appropriate fisheries management to control fishing capacity as well as IUU fishing (FAO, 2010a). Excessive fishing activities could result in overfishing categorized into three common types as shown in **Box 6** (Froese & Pauly, 2022). Increased fishing pressure beyond the level that can be tolerated by the system, for a protracted period of time, carries the risk of reaching the destructive levels of fishing. Measures to counteract overfishing should therefore be established by policymakers and promoted to the stakeholders before fishing activities reach the unsafe and unsustainable level.

Box 6. Common types of overfishing
Growth overfishing When the range of fishing mortality is above the rate of Fmax, and the loss in weight from total mortality exceeds the gain in weight due to growth.
Recruitment overfishing When the rate of fishing is above the recruitment of the exploitable stocks that becomes significantly reduced. This is characterized by a greatly reduced spawning stock and decreased proportion of mature fish in the catch. Generally, very low recruitment year after year could lead to stock collapse if prolonged and combined with poor environmental conditions.
Ecosystem Overfishing Occurs when the species composition and dominance of an ecosystem is significantly modified by fishing, *e.g.* with reductions of large, long-lived, demersal predators and increases of small, short-lived species at lower trophic levels.

Highly-efficient fishing gear, *e.g.* trawl on benthic community structures, could negatively affect the infaunal and epifaunal communities, and its effect tends to increase with the depth and stability of the substrates (Jennings & Kaiser, 1998). For example, the chronic impact of the iron dredge clam fishing includes the transformation of the benthic organism population from being a group of economic fishery species (clam) to being decomposer and scavenger (*e.g.* of the polychaetes, starfishes, sea urchins) Meanwhile, FAO (2022) summarizes the impacts of major fishing gears on the fishery resources as shown in **Box 7**.

Box 7. Impacts of major fishing gears on the fishery resources
Purse seines • Small pelagic purse seines operated with light attraction, could lead to incidental catch/bycatch of very small fishes, juveniles, or even the endangered species • The increasing practice of using encircling floating objects, including man-made FADs, increases the chances of capturing small-sized and immature fishes that aggregate around those floating objects • Incidental capture of dolphins and small cetaceans by tuna purse seines in certain fishing areas with free-swimming schools of tunas, is considered an irresponsible fishing practice, thus, special techniques have been developed to reduce bycatch of dolphins and small cetaceans, such as the Medina Panel and “back down” procedure, used to create an escape route that ensures the safety of dolphins and small cetaceans after being encircled by the purse seines
Trawls • Bottom trawls capture and frequently discard non-target sizes and species, both of fish and non-fish species
Falling nets and lift nets associated with light • The impact of lift nets and falling nets on the fishery resources depend on the selectivity of fishing net, but the major negative impact is caused by the aggregating of the fishes that are mainly attracted to the light • In addition to the target species, certain species or juvenile fishes can be attracted by the light, as well as the bycatch and sometimes discarded fishes could also be attracted, although these species could be released to safety if necessary
Gillnets and entangling nets • Gillnets and entangling nets can apply selectivity to target the size of the fish to be caught, which directly depends on the size of the mesh • Incidental catch of a number of endangered species such as turtles, sharks, marine mammals or seabirds, by gillnet and entangling net in certain areas is a matter of growing concern • Loss of gillnets generates incidences of ghost fishing, while drifting or sinking of the gear in the sea bottom is a serious concern
Traps/Pots • Juveniles or undersized species caught by traps/pots could be released alive, while the mesh size in the trap could also be adjusted to make sure that small sized individuals are released to safety • The serious issues on traps/pots are mainly focused on the lost traps/pots that would transform them into ghost gear that continues to do fishing, also known as “ghost fishing”
Longlines • Bycatch of sharks, sometimes turtles, and catch of seabirds are the main negative impacts of the pelagic and bottom longlines

During the online Meeting on Reducing Negative Impact to Ecosystem, Optimizing Energy and Fuel Consumption, and Enhancing Safety in Fishing Practices in Southeast Asia organized by SEAFDEC/TD in September 2020, the regional perspectives of the negative impacts of fishing on the fishery resources were established. Trawls had been considered by the AMSs as the topmost destructive fishing gear creating negative impacts on the fishery resources. Trawl fishing can catch various bycatch, *e.g.* juveniles and ETP species, as trawls are non-selective fishing gear whether operated in midwater and sea bottom, impacting especially on the most sensitive protected areas. In addition, some fishing gears associated with luring light except those used for squid fishing, in particular, the anchovy purse seine with luring light is also among the top destructive fishing gear which has negative impacts on the fishery resources, as operating this gear could generate catch that contains a high proportion of immature fishes. Moreover, drifting gill net with mesh size more than 10 inches has been banned in Malaysia to protect the mature size sea turtles. For the same reason, this gear with such mesh size is also not allowed to be operated in Thailand.

Furthermore, since ETP protected species, *e.g.* turtles, sharks, marine mammals, and seabirds can be mostly affected by some fishing gear, both active gear and ghost gear, modifications of such fishing gear, and improving the associated fishing practices could possibly reduce bycatch of the ETP species. FAO Technical Guidelines, *e.g.* International Guidelines on Bycatch Management and Reduction of Discards, Technical Guidelines to Prevent and Reduce Bycatch of Marine Mammals in Capture Fisheries, and so on, could support the development and implementation of policies and technical interventions to address the bycatch of ETP species in fishing operations.

Impacts of Fishing on the Habitats

Fishing activities can result in changes in the living and non-living environments. FAO (2010a) described the major concerns related to the impacts of fishing on the environment, especially on the bottom habitats. Bottom-towed fishing gears, such as trawls, dredges, and seines that are used to catch target species that live in, on, or in association with the seabed, can result in damages due to bottom abrasion and turbidity. Jennings & Kaiser (1998) concluded that the direct effects of such fishing vary according to the gears used and the habitats being fished, but the results usually include the scraping, scouring, and resuspending of the substratum that occurs against the background of natural disturbance. The damages are also caused by the fishing frequency, gear weight, and rigging. FAO (2022), AFMA (2022), and Seafish (2022) summarized the impacts of some fishing gears on the habitats as shown in **Box 8**.

Box 8. Impacts of some fishing gears on the habitats

Purse seines

- This gear does not impact on the environment because of its characteristics, and there is also no impact on the bottom habitats except when the water depth is less than the height of the seine during the fishing operations and when the lower edge of the gear swipes the sea bottom[1]

Bottom trawls

- Bottom otter trawls interact physically with the bottom sediments, which could result in removal or damage of sedentary living organisms (*e.g.* seaweeds, corals) and in the case of uneven bottom, the effect could include surface displacement of stones or other larger objects, while on flat sandy/muddy bottom, the sediments could be whirled up into the water masses and suspended
- The short and long-term impacts of bottom trawl on the bottom environment is still poorly documented, thus, more research on this aspect is urgently needed1
- It is not physically possible to trawl on reef structures as significant damage can occur if sensitive habitat areas like coral reefs, sponge beds, and seagrass beds are trawled, and to ensure that these sensitive habitat areas are protected from trawling, management arrangements such as area closures are extensively used[2]

Dredges

- Fishing with the use of the harvester method impacts on the species and the environment on the sea floor, for example, scallop harvester should only be used on mud and sand at the sea floor to limit its environmental impacts[2]

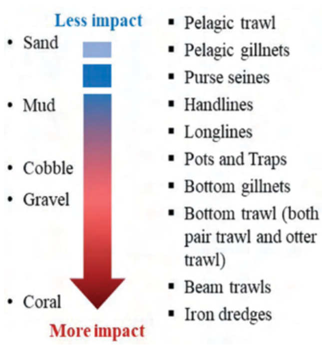
Pots

- Impacts of pots and traps on the seabed could be limited to the light contact of the traps and minimal penetration in the seabed of the small anchors or weights that are used at the end of the operations of some gears
- Although there might be some movements of the gear and the ropes on the seabed particularly in poor weather conditions, but this will not have much effect on the seabed[3]

Gillnets

- Contact of gillnets on the seabed is limited to very light contact by the footrope and minimal contact from the small anchors at each end of the gear
- As the gear is not towed over the seabed, very little abrasion3 could be created on the seabed

Nevertheless, the impacts of some gears on the habitat depend not only on the gear itself but also on the sediment type. Highly dynamic, soft bottoms (*e.g.* coarse sand, hydraulic dunes) may suffer limited damage even when exploited by heavy dredges including the hydraulic dredge. On the contrary, stable, hard, and highly structured habitats (such as coral reefs, seagrass beds, sponge beds) would be easily damaged.



(Garcia & FAO, 2003).

During the September 2020 Online Meeting on Reducing Negative Impact to Ecosystem, Optimizing Energy and Fuel Consumption, and Enhancing Safety in Fishing Practices in Southeast Asia, FAO Expert, Dr. Pinguo He recommended some technical measures to mitigate the impacts of fishing on the environment. These include:

- Closing the most sensitive areas for certain fishing (*e.g.* coral reefs, seagrass beds, nursery grounds)
- Fishing where the fish is, *i.e.* increase fishing efficiency and reduce fishing time
- Modify fishing gear and their operating methods
  - Light gears (reduce the weight of fishing gear on the seabed)
  - Semi-pelagic and pelagic fishing
- Replace intrusive fishing gears with the more habitat-friendly gears

Regional Policy Frameworks and Initiatives to Reduce the Impacts of Fishing on the Environment

The AMSs were of the consensus that it is necessary to obtain understanding and mitigate the impacts of fishing on fishery resources and the environment. Thus, the Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 adopted by SEAFDEC and the ASEAN, stipulated the need to "*Promote sound management of fishing capacity and use of responsible fishing technologies and practices…*" (Resolution No. 7); "*Intensify research on the impacts of various fishing gear types and methods on the ecosystem and populations of aquatic animals, and develop and promote environment-friendly fishing practices,* e.g. *low impact and fuel efficient (LIFE) fishing gears/methods*" (Plan of Action No. 33), "*Mitigate bycatch and discard concerns including excessive catch of juvenile fish by promoting the adoption and implementation of relevant regional and international guidelines,* e.g. *FAO International Guidelines on Bycatch Management and Reduction of Discards*" (Plan of Action No. 34).

Box 9. Improving the selectivity of fishing gears		
Fishing gear	Studies	Outcome/Constraints
Bottom trawls	• **1996:** Experiments to develop suitable Turtle Excluder Device (TED) for use in shrimp trawls, and development of the Thai Turtle Free Devices (TTFD) suitable for bottom trawl net in the Southeast Asian countries (in collaboration with the AMSs)	• Use of the Turtle Excluder Devices (TEDs) in shrimp trawl fisheries promoted in Sabah, Malaysia by the DOF Sabah and NGOs supported by DOF Malaysia
	• **2003:** Experiments to develop Juvenile and Trash Excluder Device (JTED) to reduce bycatch from shrimp trawling in Southeast Asian countries (in collaboration with the AMSs) while sorting grid was also designed to suit the bottom trawl net operated in Southeast Asia	• Enforcement of Fisheries Administrative Order No. 237 (2010) of the Philippine Bureau of Fisheries and Aquatic Resources Requiring the Installation of Juvenile and Trashfish Excluder Device (JTED) in trawls operating in Philippine waters
	• **2016:** Experiments on the use of 40 mm codend mesh size for trawl fishing in the Gulf of Thailand (in collaboration with the Department of Fisheries of Thailand)	• Enforcement of Section 67 of the Royal Ordinance on Fisheries BE 2560 (2017)
Tuna longlines	• **2004:** Experiments and promotion on the efficiency of Circle Hook (compared with J-shape hook) in longline fishing operations to mitigate the impacts of J-hook on incidental catch of sea turtles	• Since C-hooks are no longer manufactured in the region, the fishing hooks had to be ordered from outside the region where it is not convenient to order the circle hooks in small quantities
Tuna purse seines	• **2003:** Modification of the drifting fish aggregating devices (DFADs) to mitigate sea turtle mortalities in tuna purse seine fishing operations	• AMSs operate purse seines with anchored fish aggregating devices (AFAD) but it is rare to assemble the old fishing net sheet with AFAD • DFADs for tuna purse seine are deployed in the high seas, so the SEAFDEC study could be applied to support the management of tuna by RFMOs

Over the decades, SEAFDEC/TD in collaboration with the AMSs has conducted a number of experiments to improve the selectivity of several fishing gears, *e.g.* trawl, tuna longline, and tuna purse seine, as shown in **Box 9**.

From the Project "Strategies for Trawl Fisheries Bycatch Management (REBYC-II CTI)" implemented from 2013 to 2018 as a collaborative effort between SEAFDEC/TD and FAO, the lessons learned had been disseminated through the various publications that are accessible through the SEAFDEC website. Specifically, the lessons learned from the REBYC-II CTI could be summarized as follows:

- Policy, legal and institutional frameworks established or strengthened towards the establishment of area-specific trawl fisheries bycatch management plans - formulation of the fisheries management plans was facilitated while the existing mechanism of trawl fisheries management was strengthened through the application of stakeholders participatory approach under the formulation of consultative groups in local, provincial/region and national level, *e.g.* Samar Sea Fisheries Management Plan of the Philippines
- Resource management and fishing operations enhanced - led to the adoption of more selective fishing gear and practices for implementation of the zoning of fishing areas, through the studies on trawl net selectivity, *i.e.* mesh size (40 mm) and mesh shape (square mesh), where the results were applied or recommended for the local and national area management plans
- Studies on the critical fishing ground included ichthyoplankton and fish larvae conducted - and the results were applied or recommended to local and national area management plans
- Trawl fisheries socioeconomic studies including economic analysis of the impacts of 'bycatch' reduction on trawl economics carried out - supported or strengthened the management frameworks
- Ecosystem Approach for Fisheries Management (EAFM) promoted in collaboration with the relevant organizations and partners, *i.e.* FAO, APFIC, CTI-CFF, NOAA, GEF, NORAD, Swedish Government, CTSP, USAID, and national fisheries agencies of the participating countries
- Public-private partnership of trawl fisheries stakeholders initiated and strengthened to understand the co-management approach and the need for collaboration in formulating the bycatch management plans for trawl fisheries

To keep momentum on the bycatch management projects going, SEAFDEC is currently implementing "Responsible Fishing Technology and Practices" from 2020 to 2024, with support from the Japanese Government through the Japanese Trust Fund at SEAFDEC. A series of activities, *e.g.* consultation meetings, expert meetings, research and development, and capacity building programs are being implemented based on the current situation to assess the environmental impacts of fishing gear and practices on the fishery resources of the Southeast Asia region and address the national interests and concerns in mitigating the impacts of fishing gear on the marine ecosystem.

Way Forward

Measures, such as closing the most sensitive areas for certain fishing and modifying fishing gear to be more habitat-friendly, could enhance the sustainability of fisheries as the impacts of fishing activities on the environment could be mitigated. The use of selective fishing gear is also among the measures, as only the desired species and sizes are targeted but this would also entail improvements of the conservation measures. Protection of the larger or older adult and mature fishes is necessary for the sustainability of the species that are currently being utilized for human consumption. Modifications of fishing gear and operations are also necessary to reduce the bycatch of marine mammals.

In SEAFDEC (2020), the areas where SEAFDEC and AMSs could cooperate in exploring the development of new techniques and methods had been summarized, for example in fisheries research, capacity building, and education, especially on the impacts and mitigation of the impacts of fishing on the fishery resources. The topics for research and capacity building could include:

- Technologies and management to reduce bycatch and discards, including selectivity of fishing gears
- Impacts of gears, *e.g.* trawl net, seine net, and dredge, on the sea bottom
- Light and its interaction with fish behavior
- Impacts of fishing operations on ETP species including marine mammals
- Environment-friendly fishing gear materials, *e.g.* natural and biodegradable materials
- Alternative environment-friendly fishing gear other than bottom trawl
- Management concept of fishing gear selectivity has been conducted since the 1950s, thus, the need to reconsider and apply the Balance Harvesting concept
- Mitigating the impacts of fishing on the environment should reconsider the management approach
- Impacts of fishing on the habitats and critical fishing grounds, *e.g.* seagrass beds, coral reefs, nursery grounds, and so on by assessing the habitat complexity and perturbing sea beds (benthic) communities
- Effects of fishing operation on water quality, *e.g.* resuspension of sediments caused by towed bottom fishing gear, *e.g.* trawl, seine, dredge

From the Project "Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management (REBYC)" which was implemented during 2002–2008 and the Project "Strategies for Trawl Fisheries Bycatch Management (REBYC-II CTI)" during 2011–2016, it was suggested that gear modification could provide the solutions to reduce the negative impacts of fishing on the environment. Therefore, the approaches established through those projects could be applied with appropriate management concepts but should be supported by appropriate legal and incentive frameworks in introducing them to all stakeholders as well as in the decision processes.

4.1.2 Innovations for Responsible Fishing Operations

4.1.2.1 Energy Efficiency and Fuel-saving Options for Fishing Vessels

Improving the propulsion system

All movements of a fishing vessel in the water create resistance force. The vessel is subjected to dynamic force and resistance of its surroundings to maintain its moving speed. In propulsion systems, the thrust force produced must be equal to the resistance force to move forward. To minimize drag, it is necessary to improve the vessel's propulsion system. In general, direct-drive shafting at a zero-degree propeller shaft angle is the most efficient since the propeller thrust is going forward through the water current that goes straight ahead. The efficiency of the shaft angle between 0° and 6° creates small losses, from 6° to 12° gives medium losses, and shaft angles greater than 12° produce variable loading into the propeller blades (**Figure 86**). Minimizing the shaft angle could result in reduced thrust variation on the propeller (cavitation) and significantly increase the life span of the propeller. The reduced propeller shaft angle also minimizes power loss in the transmission system because the upper blade is receding from the onrushing water as it rotates up, while the lower blade is moving forward into the slipstream as it rotates down which results in uneven blade loading that can cause vibration and/or cavitation.

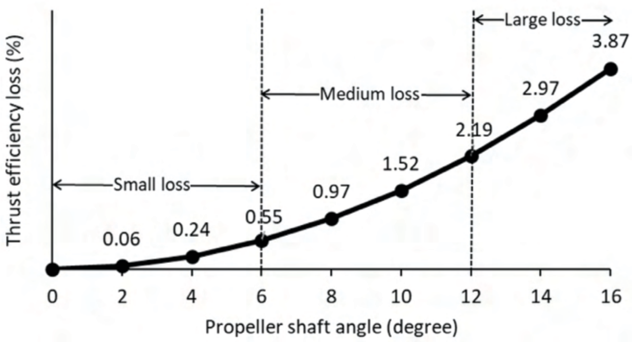


Figure 86. Thrust efficiency loss (%) in relation to propeller shaft angle (degree)

Vessel design, size of the propeller, propeller clearance, and the water flow's path to the propeller blade should be taken into consideration when constructing and/or renovating fishing vessels to improve the performance and energy use of the vessels. If the hull shape of the vessel is obtuse, it will increase the water resistance of the hull to the flow. In case the propeller clearance is small, a propeller with a small diameter should be used, although it might not be able to