History, profiles and implications of feed fish and fishmeal supply from domestic trawlers in the East and South China Seas

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Report (+ Appendix I and II) to ADMCF: June 2018

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Executive Summary

About 40 000 years ago the first modern humans made their way to Europe and began a process that transformed the ecosystems of the land from a vast wilderness to a patchwork of human dominated landscapes. Over thousands of years, many of the larger, slower growing species such as lions, the woolly rhinoceros' and aurochs died out and the large swathes of old growth forests that had grown after the last ice age were cleared to make way for farmland and urban settlements. The creation of an agricultural landscape dominated by fast-growing species took about 5000 years to unfold to the present day.

By and large the marine environment was spared the same large scale alteration until the twentieth century. The expansion of fishing in Asia, which took place after World War II and accelerated with the input of foreign aid in the 1960's and 1970's has brought about a transformation in marine ecosystem unparalleled in human history. Over the short time frame of three human generations there is now widespread evidence of ecosystem alteration on a large scale.

The vast majority of wild-harvested seafood products, both globally and in Asia, are supplied via trawling and purse seining. This report focuses on the trawl sector which is widely distributed in Asia and supplies about 40% of the total production. A very large range of species is taken with the dominant types being shrimps, squids, small pelagics (fish living in the water column such as anchovies, sardines, scads and mackerels) and a wide variety of demersal (bottom dwelling) species such as snappers, groupers, threadfin breams, lizardfishes, croakers and goatfishes, amongst many others. Asia accounts for half of the global fisheries production, yet information on the state of fisheries in order to guide management is sparse (Stobutzki et al., 2006). For example, a regional study that examined the state of demersal fisheries resources in the coastal areas of Malaysia, the Philippines and Thailand showed that, in each country, time series of scientific trawl survey data (spanning 12–49 years, depending on the area) there were substantial declines in total biomass over time (Stobutzki et al., 2006).

The trawl capture fishery sector supports a huge variety of onshore seafood handling and processing businesses including the suppliers of fresh fish for local consumption, a large processing sector that supplies frozen, salted, smoked, dried and fermented fish as well as fish pastes (for surimi and related products) and fish sauces, and a large sector that supplies fish for feed, either directly or in the form of fish meal (Fig. 1).

Supply chains are complex and reach across the world. The types of industries have changed over time as a result of changes in the main species caught due to overfishing, the development of new products and changing market demands. The growing requirement for fish for 'aquafeed' (food for the fed-aquaculture sector) has provided a ready market for the component of the catch that is, or until recently was, particularly in countries outside of Asia, simply discarded.

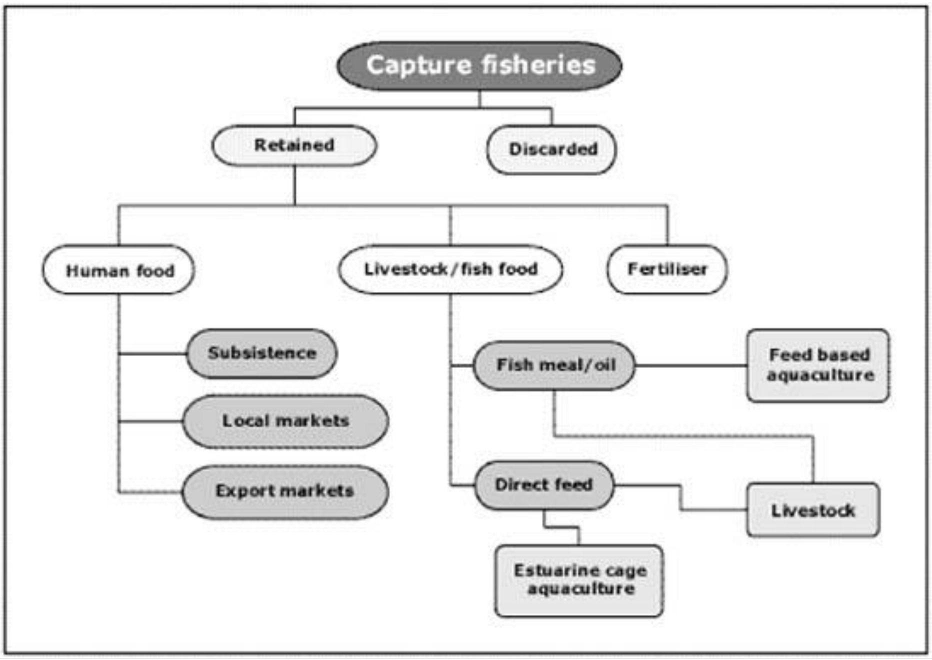


Fig. 1. Use of capture fisheries in different sectors; fish has been used as animal feed for many decades with modern surimi development starting in the 1960s in Japan (FAO 2005).

Like many fisheries in developed countries the trawl sector was developed with no controls over the number of vessels or gears that could be brought in. Moreover, as many fisheries were developed with foreign aid, these and other subsidies lowered the costs of fishing and this enabled even more vessels to enter. There are many examples around the world where the rapid rise in fishing effort causes an equally rapid decline in stock abundance and this has also been the case in Asia. In addition, even if there are regulations, for example for minimum mesh sizes, or fishing zones, enforcement is weak and growing demand for aquafeed encourages the catching of as much organic matter as possible using mesh sizes that now can be well below 1 cm, allowing little to escape (photo below).

Due to the importance of fishing as an income source in coastal rural areas governments rarely stepped in to reduce fishing effort or enforce gear or other controls, even despite growing poverty and illegal activity as fishers struggled to make a living and catches declined.

An interesting feature of these trawl fisheries has been their seeming resilience to collapse. Catches have routinely exceeded sustainable yield estimates, in some cases for decades. A closer analysis of available data has shown that slow growing, higher trophic level, species such as sharks, groupers and snapper have been overfished, sometimes to the extent of conservation concern, but that their prey has benefited from this and increased in numbers, supporting the fishery until theses too became overfished. This 'predator release' phenomenon has, temporarily, buffered the impacts of overfishing, especially as fishers have decreased mesh sizes to take advantage of larger numbers of smaller fish (Fig. 2) and management continues to be ineffective.

Trash fish catch (see coin for scale) (bottom photo); mesh size Hong Kong (upper left); processed trash fish from Vietnam (upper right), 2017; upper left and lower photo Stan Shea.

As discussed by Menasveta (2000) food security has been a predominant policy goal of regional governments in Asia and, whilst it may not have been an intentional outcome of the management strategy imposed, there have been many beneficiaries of the ‘release of productivity’ phenomenon discussed above (Christensen et al 2014). However, whilst this process may have some advantage in terms of increasing catches there are well-founded and serious concerns about how far this process (both down the trophic food web and projecting into the future) can be pushed before opportunistic species of little value such as jellyfish take over.

Asian countries now find themselves in a challenging position. There are hundreds of thousands of people dependent on these fisheries either directly via catching or indirectly via processing or other value-adding activities (such as aquaculture or surimi production). Yet the future of all these jobs and economic activities is far from secure as controls over the take of fish remain, at best, weak, at worse non-existent. Moreover, there is a growing number of species being listed as threatened, and these join a well-known list of iconic species such as turtles and sawfish that are disappearing or have, in some areas, totally disappeared.

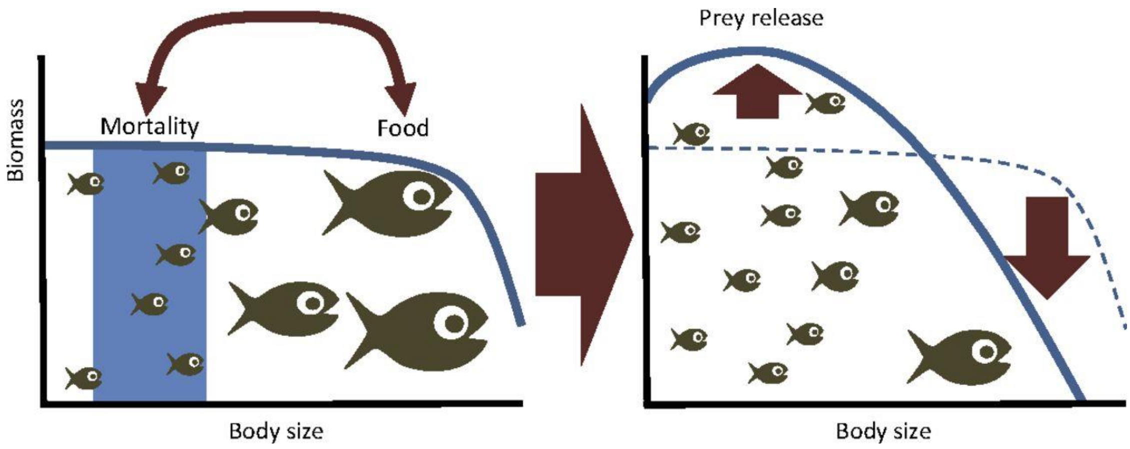


Fig. 2 How prey release leads to a large total fisheries catch. As large species are overfished, the predation mortality on their smaller prey (blue patch) is reduced 'releasing' highly productive species and allowing the fishery to catch the released production. Consequently, the catch from the ecosystem is maximized when most large species are fished out of the system (Andersen and Gislason 2017) until overfishing of the smaller species intensifies.

For decades, fisheries scientists in the region have claimed that tropical, diverse, ecosystems have attributes that demand a different approach to management compared to ecosystems in cooler waters where species diversity is lower. Factors such as different growth rates, the numbers of people dependent on fisheries production and cultural needs have not been, as argued by Asian governments, adequately addressed in global norms for fisheries management, such as single species management. However, as for anywhere else in the world, the regional marine ecosystem is biologically limited and cannot sustain unlimited pressure indefinitely.

In this report we lay out, albeit only briefly, the breadth of interaction between the trawl fisheries and the oceans they depend on and the people and industries they support. There is clear evidence of the need for reform in how the fisheries are currently managed and some important questions for governments and stakeholders to consider in regards to how the fisheries and dependent industries should be managed into the future. Given the large numbers of people dependent on these fisheries and the potential for massive disruptive social dislocation if reform is radical there is a clear need for options to be modelled and discussed with stakeholders to ensure that changes are accepted. On the other hand, inaction will lead to further erosion of benefits from the ecosystem and is no longer an option.

The lessons from other jurisdictions suggest that measures to properly match fishing capacity with sustainable yield are essential if progress on stock rebuilding and long term sustainable use is to be made. Too much fishing capacity results in low or negative profits and whilst fishermen remain poor their capacity to implement changes, such as installing technology aimed at reducing the catch of threatened species, will be low. Moreover, the incentive to cut corners and fish illegally will be strong. There is abundant evidence that, in many jurisdictions, fishing capacity is already far in excess of what is required to take the biologically sustainable yield and governments have, by and large, recognised this as a major problem. What is now lacking is effective action to move towards solutions.

This report does not cover in detail the management aspects of the fisheries. Progress on management reform needs to build on the strengths and better understanding of the current situation, such as low levels of discards (noting that European fisheries have only recently adopted zero discard policies), the variety of product streams (which may help buffer any changes in catches) and the potential for many rapidly growing species to bounce back quickly if fishing pressure is reduced, while also recognizing that fishing pressure is already excessive and must be reduced to avoid eroding future ecosystem productivity.

Overlaying these reform needs are some challenging scientific questions regarding the best approaches for managing tropical multispecies fisheries. Traditional single species approaches have proven unworkable and there is growing scientific opinion that increasing selectivity may not work in the best interests of exploited species. There is also a growing recognition and acceptance of the need to seek ways to preserve biological diversity and reduce threats to species that are particularly vulnerable to overfishing. Balanced against these and other concerns is uncertainty about what is the best way forward and we provide general recommendations for this based on this situation analysis.

Seven key recommendations and data gaps emerge from our overview of the history and current understanding of the low value/trash fish sector of trawl fisheries in the SCS and ECS regions, our field studies and review of relevant literature:

- A need for clear fishery objective-setting at the national level for management planning and prioritization of resource use (for human food, fish feed, income, etc.).
- Data collection to be conducted in a comprehensive and standardized manner to address acute data shortages on all aspects of fishing operations and resource utilisation.
- Effective management to be implemented, to include enforcement of current regulations and introduction of additional ones, with a core goal of reducing overall fishing effort and subsidies.
- Illegal, unmonitored and unregulated fishing to be comprehensively addressed in the region using modern technologies and ensuring far greater oversight of and accountability by fishing operation.
- Alternatives to using wild fish as feed through replacements or by reducing wild fish as feed by culturing lower trophic level species and increasing efficiencies.
- Gear modifications to address management goals and reduce unwanted catch, including threatened species.
- Greater consideration of and compliance with International commitments, commitments and considerations, from biodiversity to food security, equity, etc.

1 SECTION 1

1.1 General background

The fisheries of the South and East China Seas are diverse and of great importance for food and livelihoods in the region. In recent decades, however, overfishing and lack of management have allowed many of the region's fisheries to undergo declines with resulting threats to food security, jobs, and the export potential of marine resources. Combined with pollution and habitat degradation from certain fishing practices and coastal activities there are well-founded concerns for the future wellbeing of the region's marine ecosystem. In extreme cases, several more vulnerable and highly valued fishes are now at an elevated risk of extinction and in need of conservation action, such as several groupers, sharks, rays and croakers, with some marine mammals and reptiles also negatively affected by various fishing operations and other anthropogenic impacts on the marine environment, such as pollution and massive increases of plastic in the ecosystem. With increasing pressure on fisheries destined for direct human food use and with the growth of 'fed'-aquaculture that requires large volumes of fishes and invertebrates for feed, there is clearly an urgent need to better understand the condition of the region's fisheries, especially that component linked to aquaculture feed supply which is particularly poorly understood (Fig. 3). This improved understanding needs to be applied to better management, sooner rather than later.

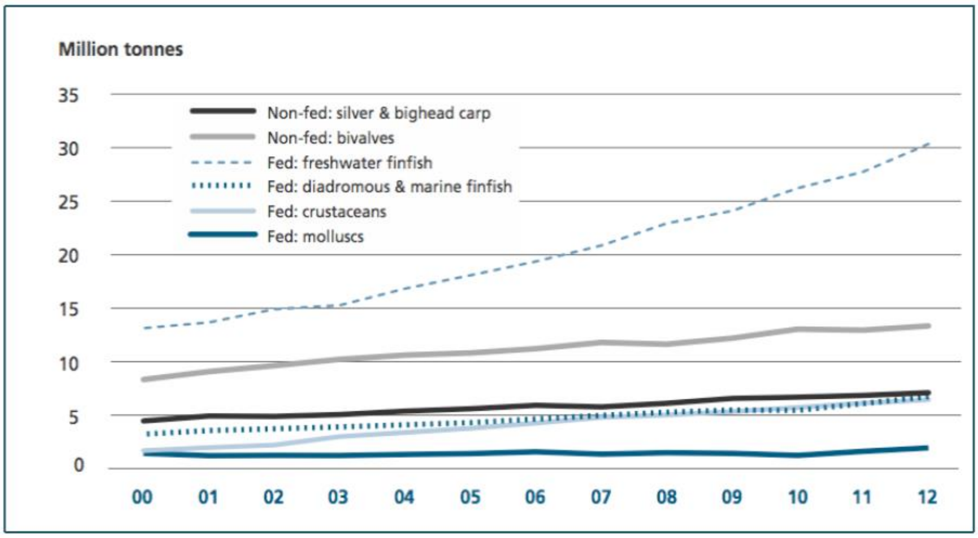


Fig. 3. Trend in aquaculture production by species group highlighting 'fed' and non-fed categories 2000-2012 (FAO 2014)

A recent modelling of future possible scenarios in the South China Sea indicated that, over the next 30 years, if current practices and pressures do not change, there will be serious and possibly irreversible losses in fish and invertebrate populations that will substantially reduce both the food and economic value of the region's marine resources (Sumaila and Cheung 2015). This 'business as usual' scenario predicts a decline in fish and invertebrate taxa by 9-59% and particularly for species more susceptible to being overfished (such as sharks and groupers) and declines of > 50% of the catch if these fisheries are not managed. Due to the general paucity of data on fisheries in the region, especially a high level of unrecorded catch, however, this initial analysis was not able to incorporate several details of these fisheries because they were either too poorly documented or unreported (Sumaila and Cheung 2015) (Fig. 4).

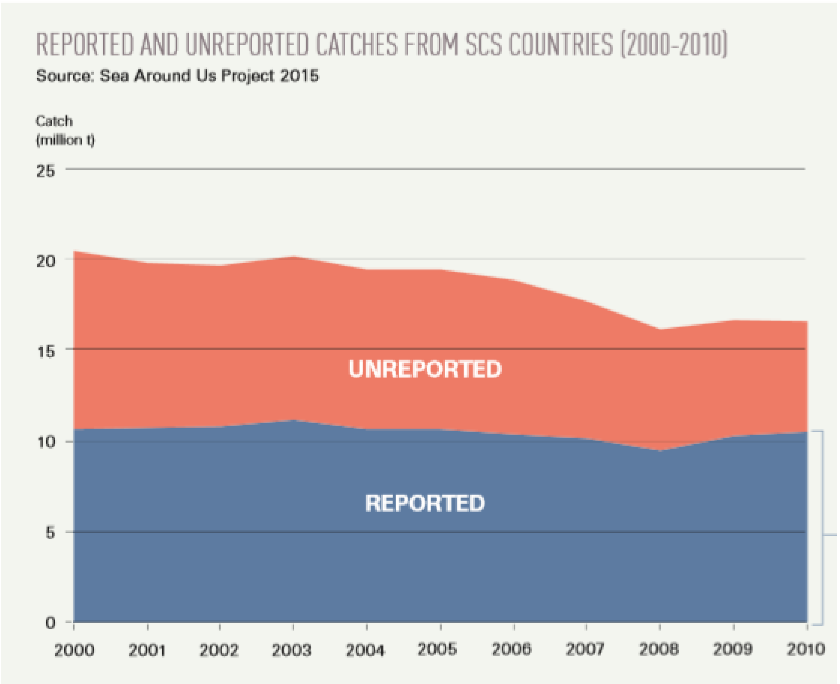


Figure 4. Estimated unreported catches in the SCS averaged about 8.1 million t annually from 2000-2010 (Sumaila and Cheung, 2015).

Particularly poorly described is a significant proportion of the catch that ends up as animal feed. Therefore, to better understand the current fishery status and to improve on analyses of the China Seas collective ecoregion the current study aimed at better understanding and documenting the feed fish component, much of which is classed as 'unreported catch' or would appear as categories of trash or mixed fish or other non specific terms (Fig. 4). The most important gear overall that takes this catch type is the trawler. Therefore, the current study investigates trawl fisheries in the East and South China Seas particularly in terms of attempting to describe species composition and volumes of fishes and invertebrates destined for fish feed (mixed fish directly fed to fishes and invertebrates and fishmeal) and non-direct human food use (such as surimi, fish balls and other processed products).

Such catch was regularly discarded in the past and variously referred to as ‘discards’ or ‘bycatch’ or ‘trash’ fish, or non-target catch, reflecting that these fishes were not specifically a target, were often discarded or were of little or no economic value (Alverson et al., 1994; Yang, 2001). Moreover, such ‘trash’ fish are often important parts of the marine ecosystem and often include the juveniles of commercially important species or their food (Chau and Sadovy, 2005).

1.2. Fisheries of the East and South China Seas; from past to present

The countries that border the East (China section) and South China Seas (Taiwan, Vietnam, Philippines, Malaysia, Brunei, Indonesia, Singapore) collectively account for the highest seafood consumption in the world and are the highest fisheries and aquaculture producers (FAO, 2016a) (Figure 5). Of these, the biggest producer in both fisheries and aquaculture is China for which these sectors provide aquatic food and income, 14 million jobs, and livelihoods for nearly 20 million people (MOA, 2017a). Yet, in China, for example, capture fishery production within its EEZ had already exceeded the estimated maximum sustainable yield (MSY) of 8 to 9 mmt (Sun, 2003; Yu, 2016) over 20 years ago (Cao et al., 2017), and, by 2016 was 66% higher than MSY indicating a clear need to reduce fishing effort (MOA, 2017a). The composition of China’s marine catches has shifted from being dominated by a small number of medium to relatively large-sized high-valued, high to medium trophic level demersal species such as largehead hairtail (*Trichiurus lepturus*), large yellow croaker (*Larimichthys crocea*), and small yellow croaker (*L. polyactis*) to multiple low-valued, small-sized, short-lived fishes lower down the food chain (Cao et al., 2017; Lundgren et al., 2006; Shen and Heino, 2014). Increasingly, as their catches declined and mariculture developed, the latter production was used to supply fish meal and feed for the aquaculture industry rather than used directly as human food (Cao et al., 2015; Funge-Smith et al., 2005; Lundgren et al., 2006). A very similar pattern also occurred in Hong Kong (Cheung and Sadovy, 2004), Vietnam (Edwards et al., 2004), Thailand and in other countries in the region (Funge-Smith et al., 2005).

Fig.5. Countries of the South and East China Seas

The loss of larger, higher trophic level, fish has resulted in a biological phenomenon known as 'prey-release' (Fig.2 and section above) whereby the removal of predators allows their lower trophic level prey to increase thereby boosting the fishery landings in the short-term. In the medium to long-term, however, without management these lower trophic level species will also eventually decrease. A significant component of these lower trophic level species in the catches today of the ECS and SCS is used as

- Raw fish used directly as animal feed for high value species such as spiny lobster and groupers
- Raw fish minced with plant materials for species like Pangasius
- Fish meal for aquaculture, pigs and poultry
- In addition the development of a range of value-added products (e.g. fish sauce, surimi, protein concentrates, fish balls, etc.) shifted the use of many species from fish feed to human food but the fishing pressure continued unabated.

Questions surrounding the use of low value fish have dominated discussions about the use of fish resources in Asia for many years (FAO 1996). When the trawl fisheries were first developed in the 1960's there was considerable discarding as the fisheries focused on a small number of species (especially shrimp) for direct human consumption. The development of aquaculture industries that required large quantities of animal proteins provided an obvious avenue to reduce the discarding and Asian countries were encouraged to make use of the bycatch (FAO 1996). The bycatch (which was referred to as 'trashfish' as initially it had no or little value, hence was discarded in favour of target species) was commonly of poor quality, comprised of small-sized mixed species of fishes and invertebrates, and had low value that did not warrant investment in chilling or ice or the space to store or time to process. Terms such as trash fish/pig fish (Cao et al., 2015; Edwards et al., 2004; Lundgren et al., 2006), low value/trash fish and duck feed (Funge-Smith et al., 2005), feed fish (Huntington and Hasan, 2009) or mixed fish feed (Chau and Sadovy, 2005), or feed fisheries that refer to fishing for forage fish or for fishmeal or fish oil (Parker and Tyedmers, 2011; Shepherd and Jackson, 2013) have been variously used.

Over time the bycatch became a valued catch in its own right such that it is currently not considered to be bycatch but a component of an overall catch that feeds different supply chains – some for cheaper options for direct and indirect human consumption and a large proportion for animal feed. The development of processed seafood industries such as the surimi industry, fish sauces, fish balls, etc. and the trawl fisheries had three main product lines – human food, processed human food and animal feed.

There is no clear and unambiguous definition or generic term for the catches of multiple, low-valued, small-sized, short-lived fishes lower down the food chain that clearly describes this component of the catch which is particularly poorly documented. The lack of a clear definition poses several challenges which can make this component of trawler fisheries difficult to discuss and to document. There are three main challenges: (1) making comparisons across studies which use different terminology; (2) lack of a focus for specific management actions or monitoring protocols, and (3) some terms (such as 'trash' fish) are actually misleading as this sector clearly now has considerable economic value, especially in Asian fisheries.

The term 'trashfish' in particular has attracted considerable discussion. On the one hand it downplays, even misrepresents, what is viewed by some as an increasingly sought-after and valuable resource used to feed land animals such as ducks and aquatic animals either directly or indirectly (via the production of fish meal). On the other, there is a great deal of overlap between the animal feed supply stream and the supply of low value fish for the poor and the increasing competition between 'feed' for fish and cheap 'food' for people is very likely to become a food security issue. Indeed, many small (inexpensive) fish (including juveniles but also naturally small species) are consumed whole by people and are a valued and affordable source of micronutrients (Lainez del Pozo 2013) for many with low incomes. Some countries do not distinguish between trashfish and low value fish (e.g. Thailand and Vietnam) but others do (e.g. China) (Funge-Smith et al 2005).

For the purposes of this paper we focus on a documentation of the demersal trawl sector due to its scale (volume of production and geographic distribution in East and South East Asia) and its relatively low selectivity which contributes substantially to the overall impacts on fish stocks and marine ecosystems. Given the timeframe of the project it was only possible to focus on one major gear type and this is the single most significant type of fishing method involved in the capture of the low value species just described. We are not taking the view that the take of small and low value fish is solely a feature of demersal trawling nor is there a judgement being made about the uses to which harvested fish are directed. The fundamental issue in many parts of Asia is that fishing pressure is too high and catches are unconstrained by management measures, whether these exist or not (Silvestre et al 2003). Constraining catches (from all gear types) is important for generating scarcity that would drive up prices and force the industry to husband the resources more closely as well as to ensure their long term sustainability and reduce threats to the more vulnerable species in the ecosystem. Moreover, we are very much aware of the potential for other fisheries to simply fill the gap if trawling is banned or restricted without removing excess fishing effort. Welcome (1976) noted that multiple gear types often masked multiple and sequential depletions in fish stocks. Whilst his work was based on African freshwater bodies, Garcia (2009) made the same observation for marine fisheries.

The resilience of species-diverse fisheries, especially in Asia, has been the source of scientific comment for many years. Multispecies fisheries (especially tropical trawl fisheries) are well known for demonstrating that yields (abundance) are maintained at a relatively wide range of effort inputs (Figure 6) after loss of larger species (larger species in the figure) or if single-species management is applied, until they too eventually decline. The reasons for this include a mix of serial depletion (in terms of areas and species – Anon 2007) and the so called 'liberation of productivity' effect discussed above.

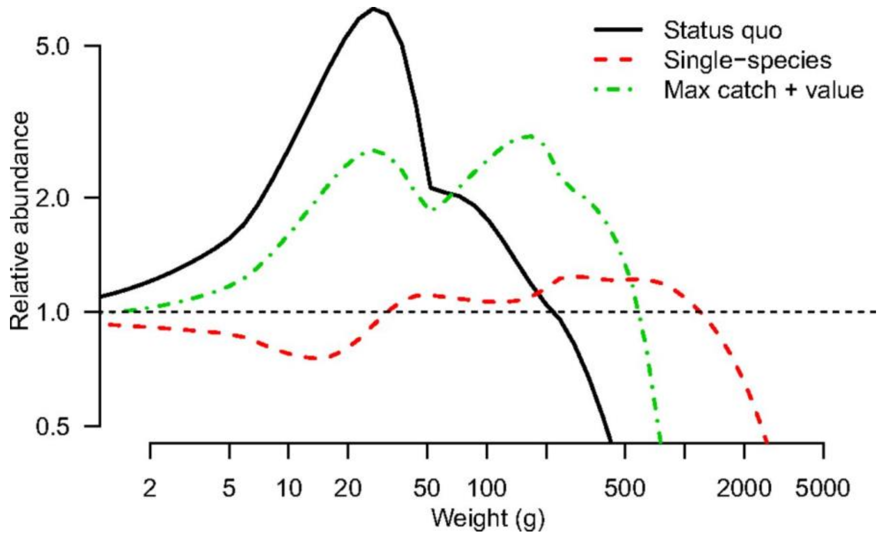


Fig. 6. Trophic cascades resulting from different management strategies implemented in the size-spectrum model of the East China Sea. Changes in abundance are relative to unfished levels, indicated by the dotted black line at a relative abundance of "1"; x *axis is the weight in grams of fish within the model (Szuwalski et al., 2016)*

Recognizing the need to better understand fisheries that are major suppliers of 'trash fish', the fieldwork component in the current study aims to investigate present status of the species composition and amount and utilization of "trash fish/low-valued fish" in two key selected countries adjacent to ECS and SCS, China and Vietnam. We had also planned field visits to Thailand and Indonesia where these fisheries are particularly significant but these field trips were not possible due to government sensitivities around trawl fisheries and feed fish catches. . However, for Thailand at least, there is sufficient publicly available information to enable a substantial contribution to the overall picture. Although several gear types are known to be involved in taking trash fish (e.g. stow net in China - Min Liu, pers. comm. Grainger et al., 2005 - and Danish seine in the Philippines), this study focused on trawl fisheries which is the major gear type supplying "trash fish/low-valued fish" (Funge-Smith et al., 2005) that is used regularly and extensively in the region and account for a high overall proportion of feed catches. Since there is no universal definition of "trash fish/low-valued fish" available, therefore in this study we focused on the fishes which were used other than for direct human consumption, either for animal feed or directed to processing plants for fishmeal/fish oil production.

Elucidating the composition and characteristics of the species in "trash fish/low-valued fish" catches is important for understanding what kinds of fisheries resources are being exploited, their current status and implications for the marine ecosystem. Management options and considerations are also discussed based on our overall findings.

1.3. Objectives of this Study

- Document the history of the low value fish feed sector of trawl catches and provide a background on trawl fishing areas, employment and relative importance of fishery production from trawling, and changes over time.
- Document the species composition and characteristics of the trawl catch component specifically associated with non-direct human use (weights/numbers/proportions/sizes).
- Identify parameters associated with the fishing and trade in 'feed' fish (trash/feed/bycatch etc. sector) where possible in relation to fishing effort, prices, fishery condition and associated practices.

1.4. Methods

Data and information were assembled using several different approaches, from field surveys of catches in fishing ports and interviews (China, Vietnam), to desktop studies and communication with experts (all countries).

Field surveys for catch composition (China and Vietnam)

For field surveys and catch sampling, ports in China and Vietnam were selected to cover a broad geographical range and to provide a representation across each country of catches taken in the coastal trawl fisheries (Fig. 7). Port selections were made following consultation with local collaborators and literature. Field sampling of fish and invertebrate catches concentrated on trawling operations (i.e. otter trawlers, pair trawlers and shrimp trawlers); trawlers can be easily identified by the presence of otter boards for otter or pair trawlers, or by extended out-triggers for shrimp or beam trawlers. The gear type of catches samples was further confirmed through conversation with the crew.

Catch sampling was conducted at peak landing times at each port whenever possible (usually early morning), as determined from consultation with local fishermen and with local collaborators. Catches were sorted by utilization purpose according to information provided by the fishermen and local experts. In the sampling protocol of this study, catches used for direct human consumption or raw materials for human food products were classified as "commercial fish" and those for production of fishmeal, processing indirectly for human food, including for animal feed, were "trash fish".

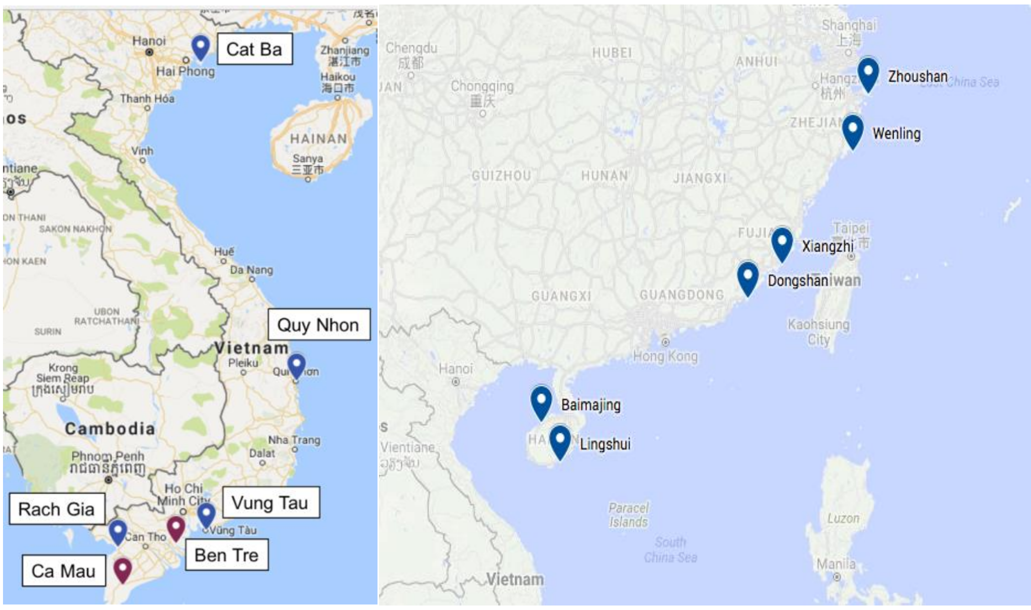


Fig. 7. Field sampling locations in Vietnam and China. For Vietnam, blue pins represent locations of both landing sites and fish processing plants while red pins represent locations of processing plants visited 29 May to 13 June, 2017. For China, blue pins show locations of fishing ports visited 6 – 19 April 2017.

“Trash fishes” were collected from randomly selected vessels to investigate species composition and size ranges of individuals caught. Scoops of “trash fish” were collected randomly from the bulk landings of selected vessels and pooled to form a single 1kg sample (per boat). Sampling was also conducted in the processing plants, when possible, during interviews because fishing vessels sometimes landed “trash fish” directly at the piers of processing plants. Samples were frozen and either sent to local laboratories for, sorting, weighing and identification (China, northern Vietnam) or shipped to Hong Kong (southern Vietnam). Fishes and crustaceans were identified to the lowest possible taxon and the abundance of each species counted. Cephalopods were pooled for weight measurements. Individual lengths (i.e. total and standard length for fish, carapace length for crustaceans) and the weights of a maximum of 30 randomly chosen individuals per species were measured whenever possible (e.g. when body was sufficiently intact). The remaining animals of the identified taxon were counted and their weights pooled. Details from these studies are provided in Appendices I and II).

Fishermen interviews (China and Vietnam)

Simple semi-structured interviews were conducted with fishers and captains at ports as well as in fishmeal plants (Appendices I and II). Questions included personal information, vessel information (e.g. size, gear type, engine power), details of last fishing trip (e.g. duration, location), catch composition and sales of landings. Questions also addressed current and perceived past trends in abundance by asking about changes noted in catches from the earliest time they remembered, sizes and selling prices of fish and any other changes in these over time. Interviews were conducted in local languages with the help of translation by local collaborators.

Desktop review and personal communications

Information and data were collected by extensive literature review in multiple languages from the region. Information collection and compilation often required translation from original languages into English for which Google Translate was used. A database of papers, organized by country, was compiled for future reference. Literature was obtained from online searches, from published and unpublished fisheries reports and after consultation with national experts in each country. Some experts kindly provided us with their unpublished data or clarified elements of published and unpublished reports.

2 SECTION 2

2.1 General Introduction on Marine Fisheries in East and South China Seas and Growth in Demand for Aquaculture Feed

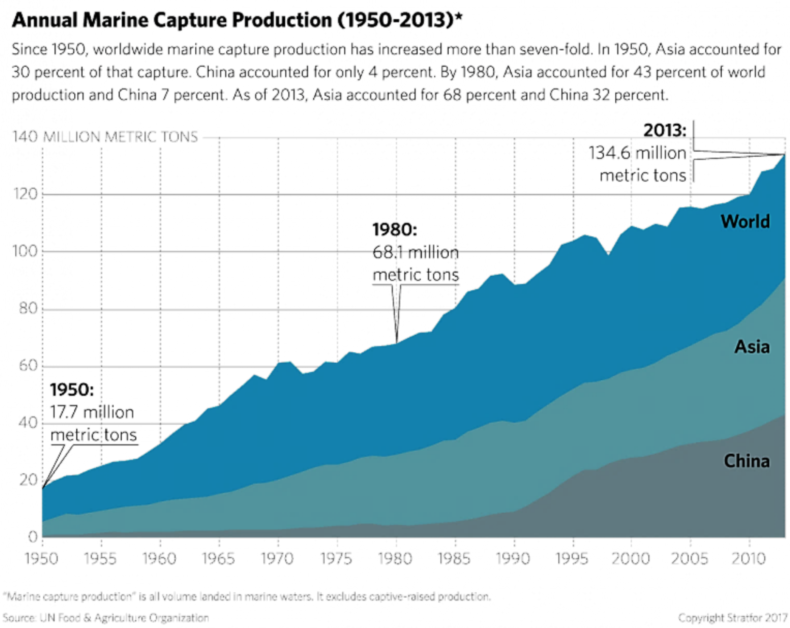


Fig.8. Annual marine capture production (FAO 2012)

Fisheries production in the northwest and west Pacific including the East China Sea (ECS) and the South China Sea (SCS) is one of the highest in the world and has grown enormously in the past 50 years (Fig. 8). The rising global demand for seafood and depletion of fisheries resources, among other things, have prompted the rapid expansion of the aquaculture sector in Asia in recent decades. As the largest aquaculture producer globally, China accounted for 55% (32,052.4 thousand tonnes) of global aquaculture production volume of 'fed' animals (i.e. aquatic animals excluding filter-feeding molluscs and aquatic plants that require active feeding by humans) in 2014., and, together with Vietnam, Thailand and Indonesia, contributed about 70% of the global production of this sector (Table 1, Fig. 8). These 'fed' animals include a significant number of carnivorous species, generally the more expensive cultured species, which require the artificial input of protein to their feed to ensure their growth and survivorship.

Demand for feed is increasing not only because of intensification of farming activities and the high value of certain carnivorous species but also because of the growing trend of providing additional feed to animals which were not traditionally fed to supplement their diets to promote growth, e.g. in tilapia, catfish and even Chinese carps (Tacon & Metian, 2008). Although there is a trend towards replacing the fish meal in fish feed with plant based materials and also using waste from food fish processing to provide much of this feed, the major source of feed remains wild capture fisheries which still play the most important role in supplying raw feed materials (Tacon & Metian, 2008; Cao et al., 2015). Hence, the growth of 'fed'-aquaculture of carnivorous and certain other species depends heavily on capture fisheries and hence on natural fisheries resources. While the 'feed' input to culturing is composed of both animal and plant ingredients (particularly soy), the animal component, globally, is about 10% and is dominated by fish (based on rough calculation of 40mmt feed produced and about 5mmt fish meal used).

Table 1. Production of fed animals (i.e. excluding molluscs and aquatic plants) in aquaculture in four studied countries (in thousand tonnes) in 2014 in Southeast Asia (FAO 2016)

	Finfish					
	Inland aquaculture	Marine/Coastal Aquaculture	Crustaceans	Other aquatic animals	Total fed animals	% of world production
China	26029.7	1189.7	3993.5	839.5	32052.4	55.6
Indonesia	2857.6	782.3	613.9	0.1	4253.9	7.4
Vietnam	2478.5	208.5	506.2	4.9	3198.1	5.5
Thailand	401	19.6	300.4	4.1	725.1	1.3
Total	31766.8	2200.1	5414	848.6	40229.5	69.8
World	43559.3	6302.6	6915.1	893.6	57670.6	

At a global level the majority of the raw materials of fishmeal and fish oil which go into fish (and other animal) feeds is supplied by directed "reduction fisheries" targeting pelagic species (e.g. *Engraulis japonicus, Engraulis ringens*, *Sardinops sagax* and *Brevoortia tyrannus*) which are seldom used for direct human consumption (Tacon & Metian, 2008; Cashion et al., 2017), although there is some interest to considering changing this, such as examining the factors around the use of nutritious Peruvian anchovy for direct food consumption rather than for fish feed (Freon et al., 2014). While reduction fisheries also exist in Asian countries (Cashion et al., 2017), a considerable proportion of raw materials directed to fishmeal production or fish feed in Asia comes, instead, from low-valued catches, which are sometimes labelled as “trash fish” or ‘mixed fish feed’ or “low-valued fish”[1] and is taken by several unselective gears, particularly trawls and set nets (Funge-Smith et al., 2005). The low selectivity of these gear types and mode of fishing operation in the case of trawls leads to a large proportion of non-target catches which are of little value for direct human food because of their size or condition. These non-target catches sometimes represented a substantial proportion of the total annual landings, such as the example of Vietnam (39%) in 2010 (Table 2).

Table 2. The volume and relative proportion of capture fishery production and trashfish/low-valued fish reported for major Asia-Pacific Fishery Commission (APFIC) countries (APFIC/FAO 2014).

Country	Capture fisheries production (tonnes)	% regional production in 2010	Trashfish/low-valued fish production in 2010 (tonnes)
China	15,665,587	32	1,280,000
Indonesia	5,384,418	11	83,600
India	4,694,970	10	
Japan	4,141,312	9	
Myanmar	3,063,210	6	
Philippines	2,615,753	5	
Vietnam	2,420,800	5	933,183
Thailand	1,827,199	4	299,628
South Korea	1,745,971	4	
Bangladesh	1,726,586	4	
Malaysia	1,437,507	3	106,404
Taiwan	851,505	2	
Cambodia	490,094	1	
Pakistan	453,264	1	
Sri Lanka	437,468	1	
New Zealand	436,640	1	
Total	48.691,243		2,702,815

As demand for fish feed grew and overall catches declined, there was growing interest to more fully utilize those catches formerly discarded as ‘trash fish’ (among other terms) and fisheries of the region moved towards full catch utilization to maximize revenue and address the growing demand for feed. In some cases, however, discards were already limited, such as in the case of China, due to a cultural ethic of conservatism which tended to result in full catch utilization (Cao et al., 2017). Moreover, as overfishing in the ECS and the SCS led to a severe depletion of higher trophic level

[1] “Fish” here refers to finfish, crustaceans and cephalopods

predators and increases in the abundance of their prey species (Watson et al., 2006) the 'predator release effect' (see above) temporarily buffered the impacts of depletions by creating new fishing opportunities, and maintained the overall catches (Costello, 2017; Szuwalski et al., 2016). As time passed, much of the resulting catch of small species and small individuals of larger species in these 'trash fish' catches, being unsuitable or too small for direct human use, went to the production of animal feeds, mainly for fish culture (Funge-Smith et al., 2005). Other uses for marine species that are not used directly for human food but are of better quality than trash fish was the value-added industries for surimi, which is highly valued in countries like Japan, and sauces and other processed products.

2.2 The role of bottom trawling

Bottom trawling is a major fishing gear in the ECS and SCS region, accounting for about 50% of regional production by weight (Sumaila & Cheung, 2015; Watson et al., 2006). In China, for example, trawling consistently provided about 40 – 50% of domestic capture fisheries production during 2012 – 2016 (Table 3). As with other gears in the region, there have been few controls on trawl fishing effort under the rapid development of these fisheries and increasing illegal fishing activities reported (Agnew et al., 2009; Shen & Heino, 2014; Teh et al., 2017). Catch per unit effort for trawlers in the SCS declined sharply in the early days of fishery development and in many areas is now well below what is considered to be sustainable (Heileman, 2009; Sumaila & Cheung, 2015).

Table 3. Domestic production of capture fisheries (tonnes) in China from 2012 to 2016. (China Fishery Yearbook 2017)

	2012	2013	2014	2015	2016
Trawl	4023278	3998037	4042451	4179386	4239580
Purse seine	908749	923652	969504	996811	1048509
Set net	1060500	468104	1025982	1029614	1002748
Gill net	1548585	1557425	1676395	1795435	1852523
Hook-and-line	258999	252646	289096	302754	312118
Other	573613	591583	578704	578762	594701
Total	8373724	7791447	8582132	8882762	9050179
% from trawl	48.0	51.3	47.1	47.1	46.8

While occasional and sporadic studies have occasionally focused on the higher value catch and "trash fish/low-valued fish" composition of trawlers in China (e.g. Jin et al., 2003; Wang & Yuan, 2008; Yang et al., 2015), Hong Kong (e.g. Chau & Sadovy, 2005), and Vietnam (e.g. Dao et al., 2005; Nguyen et al., 2014), overall a lack of detail in terms of volumes, species involved, sizes, and condition at the national or regional level, inconsistency in terminology and regarding destined use mean that collectively the bigger picture of this aspect of trawl fisheries in the region is poorly known. However, enough is known to understand that there is a problem and that the heavy use of and intense interest in 'trash fish' for animal feed represents a major pressure on the region's marine ecosystem.

2.2.1 History of the trawl fisheries and their catches

The history of the development of the trawl industry is characterised by many examples of serial depletions whereby areas and species were developed and depleted in rapid succession. The industry has also changed in response to changing species composition, the development of new products and markets, and management regimes, and overall lack of management and oversight that have resulted in poor economic outcomes and widespread illegal activity.

In the post-World War II period country governments were keen to reinvigorate the production of food and trade that had virtually collapsed during the war. The development of the trawl fisheries occurred at a time when there was a boom in the production of seafood world-wide. Know-how from Europe (e.g. German Democratic Republic), Scandinavia (e.g. Norway) and, in the early 1960's, Japan, was brought into developing countries with the aim of developing the relatively unexploited fishery resources for the benefit of local industry and food production. The expertise brought in included stock assessment expertise in the form of research vessels and stock assessment experts, equipment such as fishing vessels, and various advisors. In addition to foreign aid some governments also facilitated development via tax breaks and various subsidies (see references in Sumaila and Pauly, 2006, Mallory, 2016; Milazzo, 1998; Anon 2002).

The introduction of mechanisation into relatively underexploited fishery resources resulted in significant catches and the rapid expansion of the fleets. In Thailand, for example, the number of trawlers expanded from 99 to 5,834 in the period 1960 to 1977 (Menasveta 1980) peaking at almost 14,000 vessels in 1996 (Supongpan and Boonchuwong 2010, Adrianto et al., 2007). The research vessel in use in 1961 was able to take about 300kg of fish and shellfish per hour but this rapidly declined as the number of trawlers grew (Fig. 9). The decline in CPUE was also accompanied by a decline in the biomass of fishes.

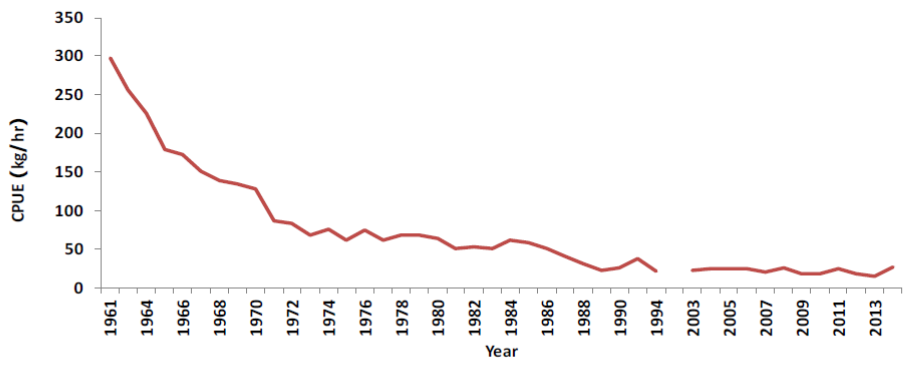


Fig. 9. Catch per unit of effort in Thailand in research vessel from 1961 to 2014 (Anon 2014).

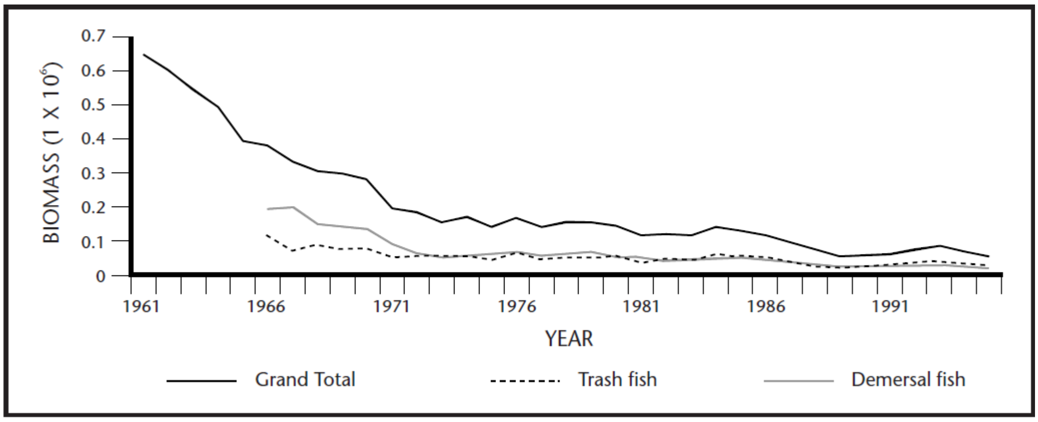


Fig. 2. Total trawlable trash fish and demersal fish biomass in the Gulf of Thailand, 1961 - 95.

Fig. 10. Decline in biomass in the Gulf of Thailand (Kongprom et al 2003) (1961-1995)

Beam trawling and explosives in the Philippines quickly restored landings to a pre-war level by 1947. An otter trawl from the US was trialled in 1947 and a US Fish and Wildlife program was established to survey the waters for fishes and shrimps. This quickly resulted in the conversion from beam to otter trawls which happened by 1953. Researchers suggested the number of trawlers that could be operated sustainably in each area surveyed but this advice was ignored and, as occurred in Thailand, the numbers were quickly exceeded. By 1954 there was comment that depletion was underway (Butcher 2004) with markedly declined biomass by the 1990s (Fig. 10). A similar pattern was experienced in other countries such as Malaysia (Abu Talib et al., 2003).

A decline in standing stock after fishing commences is neither unusual nor unexpected and, if managed properly, the biomass can be stabilised in a productive state that supports Maximum Sustainable Yield (or equivalent). However, few, if any regulations that controlled catches were brought in and the standing stock continued to decline, resulting in overfishing and financial hardship. Vessels fished harder using bigger engines and larger nets, as well as venturing further afield and staying longer on the fishing grounds. On land the construction of better cold storage facilities enabled better handling of the catches and this fuelled increased fishing pressure. This pattern was very similar to experiences in many other countries, as too was the response of government; namely to try and reduce costs by providing subsidies (such as fuel, vessel improvements) and finding, and enabling access to, new resources. This enabled fishing to continue to be profitable and attractive even as catch rates declined.

In Hong Kong, Special Administrative region of China, the shrimp fishery declined to the stage that trawlers were barely making a living. As aquaculture developed, these vessels found that what they had discarded before, the valueless fish taken in shrimp nets and usually discarded, now had value for the local mariculture sector and that (plus subsidies already in place) helped the trawl fisheries to keep going (Cheung and Sadovy 2003). However, this 'trash fish fishery' as it essentially became, further pushed down the stock until the situation was so poor that the trawl fishery was completely closed in 2012. The government paid compensation to the fishermen leaving the sector and for mariculture feed some was sourced as pellet from Taiwanese companies.

Overfishing in countries in the region variously resulted in both larger and more powerful trawlers and small, low powered trawlers, the former to exploit faster swimming fish higher in the water column and the latter to take this method to shallow waters inshore. As discussed later there was explosive growth in the so called mini and baby trawls in countries like the Philippines and Indonesia but gaining a full understanding of how this growth occurred in the early days is difficult due to lack of registration of vessels (Tulay and Smith 1982).

On the demand side, a recovering Japan had an enormous appetite for shrimp. Between 1965 and 1975 the imports of shrimp into Japan grew from 21 000 to 110 000 tonnes (Butcher 2004) and this growth continued into the 1980s. Japanese fishing companies invested in neighbouring countries either directly or via joint ventures, such as companies in Indonesia. Thus, in the early days the primary species of interest were shrimp (in the inshore areas) and various large fish (e.g. snappers and groupers and hairtails) in the offshore areas (the distance varied according to the capacity of the vessels involved and the species involved and, in some cases, their life history stage).

The biomass estimates that drove the development were commonly not species-specific and the estimates of sustainable yield were calculated across species groups on an area basis (so-called aggregate yields) and based on stock assessment models (such as Fox and Schaefer) that were developed for single species. Estimates of sustainable yields were higher than tolerable for many species which resulted in the rapid removal of the larger, slower growing, species from the ecosystems. The removal of predators resulted in a boom in prey species (as discussed above) and the fishery changed to enable these species to be captured in larger numbers. (Willmann 2005, Pauly 1987, Christensen et al 2014, Gulland 1983).

There developed an unfortunate interaction between the development of the fishery (inclusive of subsidies), the lack of management, the species taken, developing demands (as from aquaculture feed) and the seafood products available. In the early days there was considerable discarding of unwanted catch and this was deemed a serious waste of protein (FAO 1996, Alverson et al., 1994). The huge amounts of bycatch in Thailand was viewed as a resource for the newly developing aquaculture industry and the number of fish meal plants grew from six in 1967 to sixty by 1973 (Butcher 2004). Food for the poor was a key priority for developing Asian countries and the diversion of discards for direct use by people or for the feeding of animals (ducks, fish and pigs) was deemed a worthy, if not essential, solution by countries in that region.

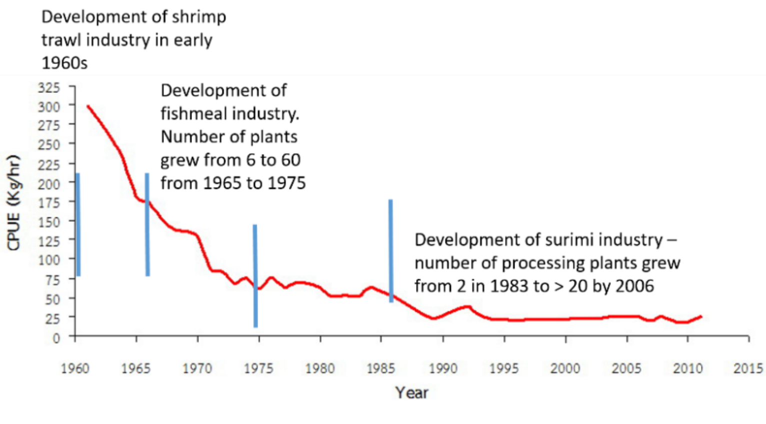


Fig. 11. Trend in CPUE over time and development of surimi sector in the Gulf of Thailand (based on Anon 2014)

Considerable research and development effort was devoted to finding ways of making use of the myriad species caught and the focus was more on better utilisation than on better selectivity (James 1998, FAO 1996, FAO and IDRC 1982, Zynudheen et al 2004) (discussed below). However, management of marine resources for these developing uses was still not forthcoming. The debate about full utilisation versus fueling overfishing remains an issue and often occurs without specifically addressing the need for management. Lobo et al (2010) comment on how the commercialisation of bycatch for sale as food or fish meal supports fisheries that would otherwise be uneconomic (and which ultimately led to the collapse and banning of the trawl fishery in Hong Kong as one example) is the reverse of criticisms from many groups about wastefulness of discarding. In the case of the Gulf of Thailand there is a close link between the development of the surimi sector and a further drop in Catch Per Unit Effort at a time when the fishery appeared to have stabilized (Fig. 11). In sum, whether used or discarded, natural resources need to be managed within their biological limits and considering international agreements and discussions around biodiversity conservation and ecosystem based management. Moreover, given limits to natural resources and biodiveisty concerns, the best use and most appropriate and efficient use needs to be considered, whether this be for direct human use or indirectly as animal feed.

In a review of the development of the surimi industry in South East Asia, Pangsorn (2009) noted how the industry had developed in order to utilise bycatch from trawling activities. In Thailand the industry first started to develop in 1983 as a mechanism for adding value to fish that was previously sent for fish meal. Over the period 1983 to 2006 the number of surimi plants grew from 2 in the region to 57 in Thailand, Malaysia, Vietnam and Indonesia. In 2005 the total production from these countries was estimated to be about 315,000 tonnes (including fish balls and similar products) (equating to about 1.2 million tonnes of raw fish). China also developed a surimi industry and produced 361,242 tonnes in 2004 following a rapid increase from 46,810 tonnes in 1994 (Vidal-Girard and Chateau 2007). Zhao and Shen (2014) record an increase in production from 242,700 tonnes in 2010 to 309,240 tonnes in 2015, and whether the drop from 2004 to 2010 is real or an artefact of the way the data are collected is also unknown.

The surimi sector includes a diverse range of products

- Fish Ball
- Fish Cake
- Kamaboko
- Fish Sausage
- Battered & Breaded Products – e.g. Nugget, Burger, Fish Finger, Patented Shrimp, Imitation
- Crab Meat, Fish Filament
- Fish Noodles
- Fish Roll
- Chikuwa

According to Vidal-Giraud and Chateau (2007) the global surimi market at the time of their work was about 2-3 million tonnes but accurate production figures are very difficult to obtain. Tropical fish based surimi dominates production and China dominates the country based production figures (Seaman 2014).

As documented by Mansfield (2003) the development of the surimi industry was facilitated by SEAFDEC via Japanese companies (SEAFDEC has had a very close relationship with Japan). Value-adding so called 'bycatch' turned this bycatch into a sought-after catch and created a higher overall value for the trawl catch, despite declining catch per unit effort and declining catches of high value species. Moreover, the shift of material away from the fish meal plants was compensated to a degree by the direction of waste products from fish paste production into fish meal, with many surimi plants having a co-located fish meal production facility. Thus the overall efficiency of the industry is very high as there is little waste (for more on surimi see below). But again, fisheries that supply the sector were not and are not managed for biological sustainability.

2.2.2 Challenges in managing trawl fisheries

The expansion of fishing in general, but especially of trawling, resulted in considerable conflict with local fishers. The trawl fleets were capable of rapidly depleting local fish and shrimp stocks and the trawl vessels commonly interacted with local fishing gear resulting in its removal (Pomery et al 2007, Salayo et al 2006, Bavinck and Garuvahanan 2006, Cheung and Sadovy 2005). Efforts by authorities to separate the fleets via inshore closures proved ineffective as the trawlers simply flouted the laws knowing that local enforcement was either incapable or unwilling to police them. Part of the issue was the presence of far too much fishing capacity which reduced profits to zero and provided incentives for trawl operators to enter closed areas. In western Indonesia and Malaysia there were many violent confrontations between local fishers and trawlers which resulted in the Indonesian government banning trawlers in the western part of the country in 1980 (Butcher 2004). The ban proved effective in terms of rejuvenating fish and shrimp stocks but trawl vessels slowly returned via a variety of arrangements such as developing slight modifications to the gear or making use of new gear or novel naming (e.g. using Danish seines, known as cantrang) or via corruption (Butcher 2004). Moreover, the ban simply shifted effort into the purse seine fisheries for small pelagics and the cycle of overinvestment and overfishing shifted to another group of species (McElroy 1991).

Overfishing not only forced the trawlers into inshore fishery areas but also into the waters of neighbouring countries. However, in the case of Thailand the declaration of Exclusive Economic Zones under the 1980 Law of the Sea forced some of these vessels back to Thai waters (McDorman 1986), thus compounding the overfishing and conflict problems. The remainder simply operated illegally (Butcher 2002, McDorman and Tasneeyanond 1987) or under various licencing/joint venture arrangements (Lymer et al 2008). Occasionally Burmese, Vietnamese and Malaysian authorities would conduct enforcement exercises and seize vessels fishing illegally but these ventures were short-lived and, in the long run, ineffective. The Thai government did not remove excess fishing effort and instead facilitated joint fishing arrangements regionally and further afield in Oman and India. Illegal, Unregulated and Unreported (IUU) fishing remains a major problem in the region (Agnew et al 2009, BOBLME 2015, Funge Smith et al 2015, Anon 2008, Palma and Tsamenyi 2008)

Hence the trawl fisheries faced a 'perfect storm' of conditions and factors that, on the one hand prompted further fishing and on the other made reduction in fishing effort extremely problematic once serious declines became apparent. The 'storm' conditions included the multispecies nature of the (mostly) tropical fisheries, non-selective gear, poverty, cultural factors, food security, livelihoods, mariculture development, subsidies, illegal and unregulated fishing, predator release and lack of effective management.

Developing countries in Asia have faced a large number of pressing issues in regards to their fisheries. The development history reveals some repeating themes which point to the struggle that nations have undertaken in seeking to get their fisheries under control. There have been many attempts to remove illegal vessels from nation state waters, two attempts to ban trawling (in Indonesia), banned trawling in HKSAR, and many attempts to cut fleets and implement technical measures such as larger mesh sizes and bycatch reduction devices. Illegally small mesh sizes remain a major issue in several countries. There are multiple references to authorities ignoring advice about not exceeding suggested vessel numbers (e.g. Philippines and Thailand) or ignoring scientific advice to cut fleets (Butcher 2004) and even criticisms of scientists over their inappropriate advice to governments (Pauly 1987).

By failing to act, the authorities have created incentives for the industry to cut corners in order to cut costs while the lack of control on vessel numbers means that, on average, income is insufficient to make a suitable profit. All of this was predictable from both economic theory and practical experience and the outcomes in Asia are due to the largely open access, and largely unmanaged, nature of the fisheries that sought to prioritise social and economic objectives over effective resource management. The industry has resorted to illegally accessing closed areas, the avoidance of licencing/registration, corruption, illegal mesh sizes, smuggling (fuel, guns and drugs) and the use of slave or poorly paid labour (UNODC 2016, Anon 2008, Rose and Tsamenyi 2013, Rose 2014, Butcher 2002, Topsfield 2017).

2.3 Managing multi-species fisheries in Asia

However, there are also a number of other issues which have made managing these fisheries harder than is the case in many northern hemisphere developed countries where marine ecosystems are different and the needs of the people less pressing. Some of the issues defining the current state and character of the fisheries include:

1. The tropical, multispecies nature of the ecosystems – there are a number of attributes of the species and ecosystems that make the response of tropical systems different to those in cooler parts of the world. For example, growth rates in many species are faster and high species diversity may make the ecosystems more tolerant to fishing pressure, at least in the short term. Managing all species at MSY in diverse systems may also do damage (Walters et al 2005) and thus different management approaches are required.
2. Technical, practical and financial challenges associated with multispecies management - the large number of species makes it impossible to do formal stock assessments and thus alternative approaches are required. Over the past few decades single species models (e.g. Fox and Schaefer) have been applied to multispecies complexes but these have consequences in terms of ecosystem shifts. Other, new approaches (e.g. ecosystem modelling, indicator species) have been developed and need to be evaluated for their ability to form the basis for workable management. The multi species nature also makes monitoring very difficult and expensive.
3. Poverty and rural dependence – whilst there have been some major demographic changes in the past few decades there remain large numbers of coastal dwellers that live in poverty and for whom fishing is either a way of life or the main source of animal protein (Menasveta 2000). In some areas, such as eastern Indonesia rural poverty is linked to political stability

(Resosudarmo and Jotzo 2009) and fisheries provide one of the few means for people to access food and employment (Funge-Smith et al 2005).

4. The wide variety of fishing gears (see for example, Philippines) that have been developed over decades if not centuries by fishers seeking to exploit species with varying habits, living in different habitats and at different stages of their lifecycle.
5. Culture – whilst all coastal peoples have a cultural connection to the sea and its fisheries there is a belief amongst some fisheries bodies in the region (see SEAFDEC below) that the diversity of relationships with the sea, and tastes in food, have, in combination with the range of species available, created demand for anything that can be supplied.
6. Source of development and export revenue - fish exports thought to be very important for development and a key source of income but policies facilitating this have not dealt with the need for controlling exports to within sustainable limits or against national food security needs
7. Capacity to manage – investment by governments in fisheries management skills and capacity has been inadequate for the task at hand. Agencies have regularly opted for soft options such as diverting excess fishing effort into other areas and fisheries without considering the consequences. A lot of money has been put into mariculture sectors of government and diverted from fisheries.
8. A challenge to the established approaches to the Ecosystem Approach to Fisheries Management or Ecosystem Based Management (EBM) which currently seek to minimise the changes to marine ecosystems arising from the exploitation of fish stocks. Whereas traditional fisheries management seeks to maximise the productivity of individual species via altering population structures to favour faster growing fish, the approach in Asia (more by accident than design) has been to alter the ecosystem by favouring species that are faster growing. However, both approaches can lead to overfishing if not managed.
9. Some government policies focus more on enhancement via restocking and artificial reefs than they do on ensuring pressure on wild resources is kept under control or within biological limits. Also, the development of aquaculture/farming was/is sometimes perceived to be both a solution to overfishing and the answer to future seafood supply (e.g. Lai and Yu, 1995).
10. Subsidies, as in many other places, is a particularly difficult challenge in respect of their removal given the high need for livelihoods (e.g. Mallory 2016).

2.4 Regional responses – utilization versus selectivity and other perspectives on fishery management

The response of Asian nations to a combination of their regional circumstances and the issues described above has been characterised by a mix of pragmatism and arguments in favour of different approaches to fisheries development and management for the region. The response is succinctly articulated by the South East Asian Fisheries Development Centre (SEAFDEC) in its introduction to its regionalisation of the FAO Code of Conduct for Responsible Fisheries (CCRF) when it stated (SEAFDEC 2003):

> *During the negotiation process, specific regional issues were diluted, or perhaps even avoided, with a view to finding an acceptable global compromise and consensus on controversial issues.*

The negotiation process referred to was the development of the FAO Code of Conduct for Responsible Fishing (CCRF) but there has long been a concern about how tropical and multispecies fisheries were dealt with at an international level, especially by developed countries. The regional issues alluded to were far from trivial and, in some cases, go the heart of interpretations of the Law of the Sea (see below). In arguing the case for a regional interpretation of the CCRF, SEAFDEC made mention of significant difference in the region's fisheries when compared to the rest of the world which could be summarised as:

- Traditions and culture – which underpin the diversity of seafood products consumed;
- Fishery structure – which focuses on the importance of small scale fisheries, especially in rural areas, and
- SE Asian ecosystems – the tropical, multispecies nature of marine ecosystems requires different management approaches.

A key point of departure was the region's commitment to full utilisation rather than selectivity which was part of a suite of measures aimed at improving food security and commerce driven by global concerns about reducing wastage and making better use of underutilised species (FAO 1996)).

The push for selective fishing had arisen out of growing concern in many countries about the impacts of fisheries on non-target species and this was increasingly being reflected in international agreements and guidance documents. However, many Asian nations did not agree with the target/bycatch dichotomy, preferring to consider everything as a target but with some separation into high and low value species (Funge-Smith et al 2005) but also, at times target and incidental catch (SEAFDEC 1999, but only in regards to industrial fisheries). The definitions have varied over the years but, broadly, one basis for questioning the value of categorisation is that:

> *"…..the same species can move from one category to another depending on size, season, market demand, season or other criteria……"*

It may seem an esoteric argument as to what category a species is allocated but the obligations for state signatories to the UN Law of the Sea Convention differ for target versus non-target species (also note the challenges in terminology around bycatch/discards/trash fish/feed fish which can make documentation a challenge. For target species States are expected to:

> *LOSC Article 61(1) The coastal state shall determine the allowable catch of living resources in its exclusive economic zone:*
>
> *61(3) MSY ' as qualified by relevant environmental and economic factors, including the economic needs if coastal fishing communities and the special requirements of developing states and take into account fishing patterns and the interdependence of stocks*

For non-target species the expectations are

> *61(4) associated species to be above the levels at which their reproduction may become seriously threatened*

(see also straddling stocks agreement Article 5e – which, in regards to species associated or dependent on target species, refers to 'maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened;)

Thus the management performance expectations for 'bycatch' are lower in performance than those for 'target' species and focused on preventing irreversible harm to reproductive capacity, not maximum sustainable yield.

The UN Straddling Fish Stocks Agreement, whilst promoting conservation of fish stocks also makes reference to:

- Optimum utilisation (Article 5a);
- Reducing discards and bycatch (Article 5f), and
- Development and use of selective fishing gear (Article 5f).

Reducing discarding can be achieved in a variety of ways, including greater use of the species taken. The concern expressed at the time was more about discarding, as opposed to the nature of the market to which the fish were directed or resource sustainability. Thus, the increased diversion of species normally discarded to a market was seen as a positive step and providing fish for direct human consumption was seen as more beneficial than providing fish for animal consumption, and management of fishing effort was not seriously considered.

Whilst there was concern over the mortalities of juvenile fish, many Asian countries took the view that seeking to manage the fisheries for the production of high value species resulted in the potential loss of a large amount of protein from naturally small species that could be used as food for the poor. By the time the conferences and meetings on food security and discarding were taking place (mid 1980s onwards), not only were there substantial dependent (processing) industries in place in countries like Thailand but resource status had declined precipitously and research efforts aimed at making use of low value fish were underway.

The Regionalisation of the CCRF was supported by a series of guidance documents, one of which covered responsible utilisation (SEAFDEC undated). Regional governments elaborated on the optimal utilisation theme in seeking to provide a regional interpretation of responsible use.

<u>FAO CCRF</u>

11.1.8 States should encourage those involved in fish processing, distribution and marketing to:

a. reduce post-harvest losses and waste;
b. improve the use of by-catch to the extent that this is consistent with responsible fisheries management practices; and
c. use the resources, especially water and energy, in particular wood, in an environmentally sound manner

<u>SEADEC additions</u>

11.1.8 ADD. 1 Optimizing utilization of catch

> Introduce and provide support for the development of technologies to optimize the utilization of catch and reduce post-harvest losses, wastes and discards in industrial and small-scale fisheries and processing operations though improved processing facilities, on-board and on-shore handling, storage and distribution of fish and fishery products. (Millennium Plan of Action, paragraph 1 of Sustainable Utilization of Fish and Fishery Products) (ASEAN-SEAFDEC 2002)

Article 11.1.8 ADD. 2 Maximum Utilization of catch

Promote the maximum utilization of catch, including the reduction of discards and post-harvest losses to increase fish supply and improve economic returns (Millennium Resolution, paragraph 11) (ASEAN-SEAFDEC 2011)

<u>FAO CCRF</u>

11.1.9 Human consumption use - States should encourage the use of fish for human consumption and promote consumption of fish whenever appropriate.

<u>SEAFDEC additions</u>

States should encourage the proper handling and quality preservation of fish of low economic value for direct human consumption, taking into consideration economic factors.

> States should encourage the maximum utilization of under-utilized species of low-economic value (including pelagic fishes) for direct human consumption taking into consideration socio- economic factors.
>
> States should promote greater fish consumption of under-utilized fish through public education on the beneficial effects of these fish on human health and the way to prepare them.

These sentiments have been adopted in regional forums such as the ASEAN/SEAFDEC Plan of Action (SEAFDEC 2011) -

> *58. Introduce and provide support for the development and application of technologies that optimise the utilisation of catch, reduce post-harvest losses, wastes and discards in commercial and small-scale fisheries and processing operations, through improved processing, facilities and infrastructure development, on-board and on-shore handling, storage, distribution and marketing of fish and fishery products.*

In other approaches to depleted natural resources and moves to downsize the fishing industry, the Chinese government implemented the Fishermen Transfer and Fishery Transition Programme in 2003 with the aim of moving fishermen to other industries such as fish processing, coastal tourism, and mariculture but the programme suffered from limited inspection by local governments, the continued presence of illegal fishing vessels, and a continuation of entrants into the fishing industry despite the transfer program (Cao et al., 2017).

3 SECTION 3

3.1 Trawl gear types, numbers, production volumes and areas fished

Pair trawlers Cat Ba Island, Hai Phong, Vietnam May 2017

3.1.1 The use of trawls in Asia

This section seeks to document the nature of the demersal trawl fisheries in the target countries so as to gain an understanding of their characteristics, development and role in the seafood economy. Trawling is the major supplier of low-value fish for animal feed and surimi overall and hence their role in these components of the regional marine fisheries are particularly relevant to understanding the characteristics and ecosystem implications of the catch and regarding their role in regional fisheries management.

A clear picture of the trawl fisheries is difficult to assemble due to a mix of:

- dated information - policy or other (e.g. economically driven) changes that may not be reported or are not being implemented or effective.
- definitional issues and lack of clarity around gear type – e.g. not separating gears or landings by demersal from pelagic trawls which has implications for interpreting impacts.
- Illegal, Unregulated and Unreported (IUU) fleets – some, especially inshore small-scale fleets, can be large and may not require licencing. Misrepresentation of trawler size or type

may happen due to licencing and access issues. Lack of registration requirements for certain classes of vessels, especially small scale vessels. One example is the so-called 'mini trawls' which proliferated in Indonesia following the first trawl ban in the 1980s. These vessels were believed to not be officially recognized as trawlers as set out in regulations. Moreover, the mesh sizes used by some vessels can be much smaller than stipulated by law.

- Misclassification – either due to under-measurement or misclassification vessels registered as small vessels may indeed be longer or have a higher engine power than permitted (see for example Ramiscal and Dickson, 2010).
- Double counting where vessels are required to be registered under more than one jurisdiction.
- Use of variations to standard trawl methods in order to evade documentation and the law.
- Poor documentation of catches which are known to vary amongst gear variants (otter trawls, pair trawls, pelagic trawls at a basic minimum).

3.1.2 Types of trawl gear in use in Asia

Trawling is one of the most widely used fishing methods used in Asia, the other being purse seining. Depending on country, trawling accounts for between 25% and 52% percent of the catch (Funge-Smith et al 2012). There are an estimated 83,000 trawl vessels in the member countries of the Asia Pacific Fisheries Commission (APFIC)(see http://www.fao.org/apfic/background/about-asia-pacific-fishery-commission/membership/en/ and this is likely an underestimate. Not only has the number of vessels increased over the decades but so too has the area subject to trawling (Watson et al 2006).

Defining fishing gear can be problematic as there are many variants that straddle not only the criteria that separate trawl from other gear types but also the criteria that separate one type of trawl gear from another. Examples of the first challenge include towed gillnets and Danish seining. Gillnets are most commonly deployed as static gear which rely on fish swimming into the net which is either set on the seabed or floating in the water column (http://www.fao.org/fishery/geartype/219/en). However, in some areas gillnets can be towed (very slowly) by a vessel and this active movement embodies one of the key characteristics of trawling (Dudley and Tampubolon 1985). Danish seining is another example whereby a net is used to encircle fish on the seabed in a similar manner to a purse seine but the ends of the net are towed together to ensure that the fish are trapped, rather than bringing together the bottom of the net by pursing.

In terms of the second category (i.e. excluding towed gillnets), there is overlap between the different types of trawling, especially demersal, otter trawls and pelagic trawls, which are described in more detail below. The type of net is one factor determining the range of species taken and the degree of environmental impact and so being able to categorise the type of net being used is important for generating an understanding of overall potential impacts.

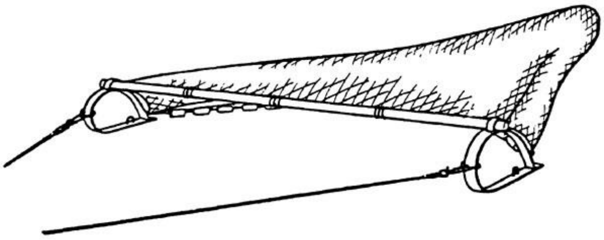
In broad terms a trawl is a triangular shaped net that is pulled through the water column by a moving boat (or boats). The net can be run along the seabed, in which case it is known as a demersal trawl, or it can be located in the water column itself where it is known as a midwater or pelagic trawl.

The entrance of the net can be kept open in three possible ways; the use of a rigid bar across the entrance to the net (beam trawls), the use of hydrostatic forces operating on wooden or steel plates that push outwards as the net is towed (otter trawls) or by the use of two vessels, each of which tows one side of the net (pair trawls). Each of these is described in more detail below.

Beam trawls

According to the FAO (http://www.fao.org/fishery/geartype/305/en).

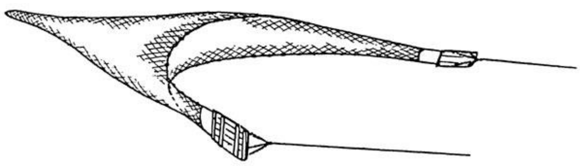
> *A beam trawl consists of a cone-shaped body ending in a bag or codend, which retains the catch. In these trawls the horizontal opening of the net is provided by a beam, made of wood or metal, which is up to 12 m long. The vertically opening is provided by two hoop-like heads/shoes. The trawl mostly made from steel. No hydrodynamic forces are needed to keep a beam trawl open.*



Beam trawling is generally undertaken by small (approx. 10m) vessels fishing close inshore for shrimps. In comparison to other forms of trawling, the number of vessels is generally quite small (see below). Vessels may tow a single net or multiple nets. Due to the main species of interest being shrimps the mesh sizes are small (10mm or so) and this results in relatively large numbers of small and juvenile fish.

Otter board trawling

The net can also be kept open by the pressure of moving water operating on flat plates (made of wood or metal) attached to the front of each side of the net. These trawl doors are often called otter boards and demersal trawling is commonly called otter board trawling (http://www.fao.org/fishery/geartype/306/en)



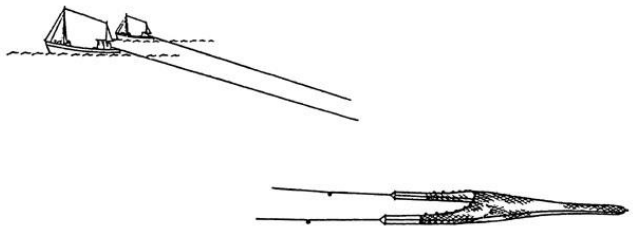
There are several variants employed as a result of environmental differences (seabed or other environmental conditions) or local innovations/capacity. Trawlers may tow two nets (twin trawls http://www.fao.org/fishery/geartype/208/en) or even more. A variant known as boom trawling simply describes the common practice of using booms projecting out from either side of the vessel to increase the spread of the net.

Otter trawl vessels come in a wide variety of sizes and fleets of small vessels (so called 'mini' trawls and 'baby' trawls (see Philippines below) targeting shallow, inshore areas are common throughout the region.

Pair trawling

According to the FAO (http://www.fao.org/fishery/geartype/307/en) pair trawling involves:

> *Two vessels, each towing a trawl warp attached to the bridles in front of the two trawl wings. One of the vessels is handling the trawl and takes the catch. The other is only a towing vessel, the so-called "slave".*



Pair trawling can be used for both demersal species and pelagic species. Pelagic pair trawling has grown in popularity as demersal resources have declined and pelagic resources have increased plus the returns for effort are higher.

Catching pelagic fish requires faster towing speeds which are generally not achievable by many trawlers and engine upgrades are challenging due to the low rents. Pelagic species are also taken in demersal trawls, especially in shallow water but also as a result of net modifications aimed at making the top of the net ride higher in the water column (so called high lift trawl nets) (Ramiscal and Dickson, 2010). There can be some further overlap as midwater trawls can be deployed so close to the seabed that bottom contact does occur.

3.2 Trawlers by country – numbers and production

3.2.1 Thailand

In Thailand the trawl fleet was developed through a bilateral agreement between Thailand and Germany in the 1960s (Morgan and Staples 2006, http://map.seafdec.org/Monograph/Monograph_thailand/trawl.php) which created a rapid expansion in fishing effort.

The most common trawlers are otter trawls, followed by pair trawlers and beam trawlers which in 2014 numbered 2006, 988 and 105 respectively (Anon 2016) – the lowest number since the fishery started to grow in the mid 1960's. The vast majority of these vessels were located in the Gulf of Thailand which reflects the larger area of trawlable ground compared to the Andaman Sea. During the period 1970 to 2006 the number of registered trawlers (of all three types) in the Gulf of Thailand grew from 3,082 to 4,604 but was highly variable over the years with a peak in 1990 and an overall decline since then especially, for beam trawlers and otter trawlers. The relative growth in the number of pelagic trawlers reflects the increasing interest in small pelagic resources, which may well have benefited from the removal of predators (Hutchings and Baum 2005, Link et al 2002, Caddy and Garibaldi 2000). A breakdown of the catches by gear type for 2000-2014 is shown in Figure 12.

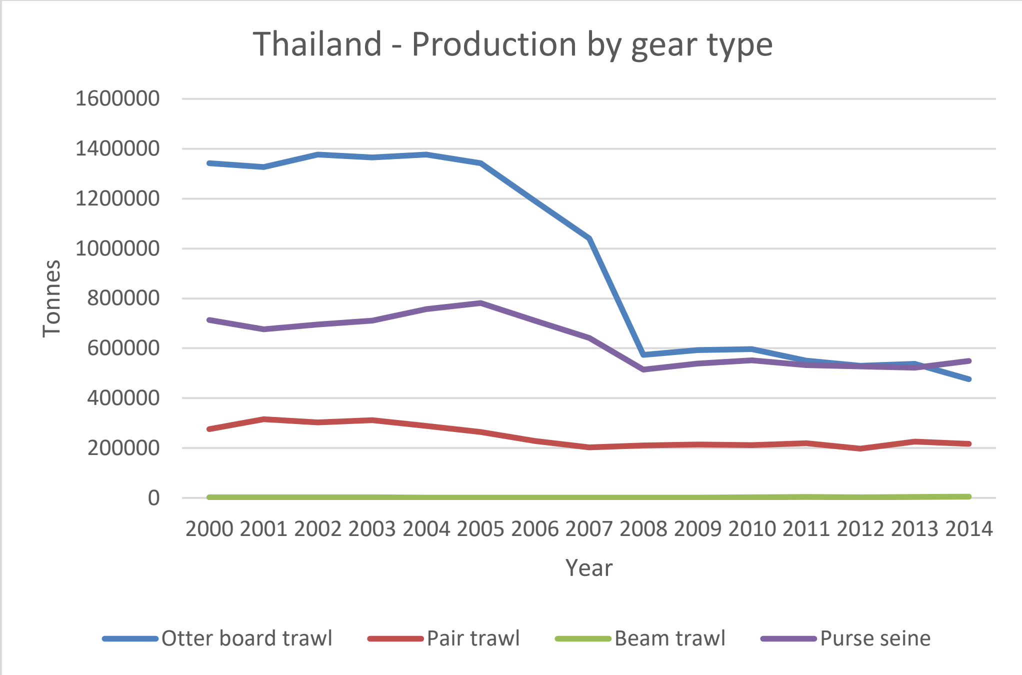


Fig.12 - A breakdown of the catches by gear type for 2000-2014 (Thai Department of Fisheries yearbooks-Anon 2014)

The number of trawlers in Thailand increased rapidly after this gear was introduced in the 1960s. According to Boonyubol and Pramokchutima (1984) the number of trawlers grew from 60 in 1960 to almost 8,000 in 1980 with a peak of some 13,000 in 1989 prior to the start of a long decline. According to Supongpan and Boonchuwong (2010) the number of all types of trawlers had declined to 7,226 in 1995, then to 5,566 in 2000. By 2015 the total number of registered trawlers had declined to 3,099 (Anon 2016), noting that the Thai Fisheries Management Plan lists the number as 4,087 following a survey in 2015 which identified 1,236 trawl vessels operating illegally. A reduction to less than 3,000 vessels would take the fishery back to the level seen in the mid 1960s when Catch Per Unit Effort was about half that when the fishery started and to a level less than MSY (assuming that stocks would rebuild).

In Thailand the overall number of trawlers has declined but the number of otter trawlers has declined by a greater proportion such that pair trawlers now represent a larger percentage of the fleet than in the past. Note that the reduction in trawler numbers has continued (as discussed above) (Fig. 13).

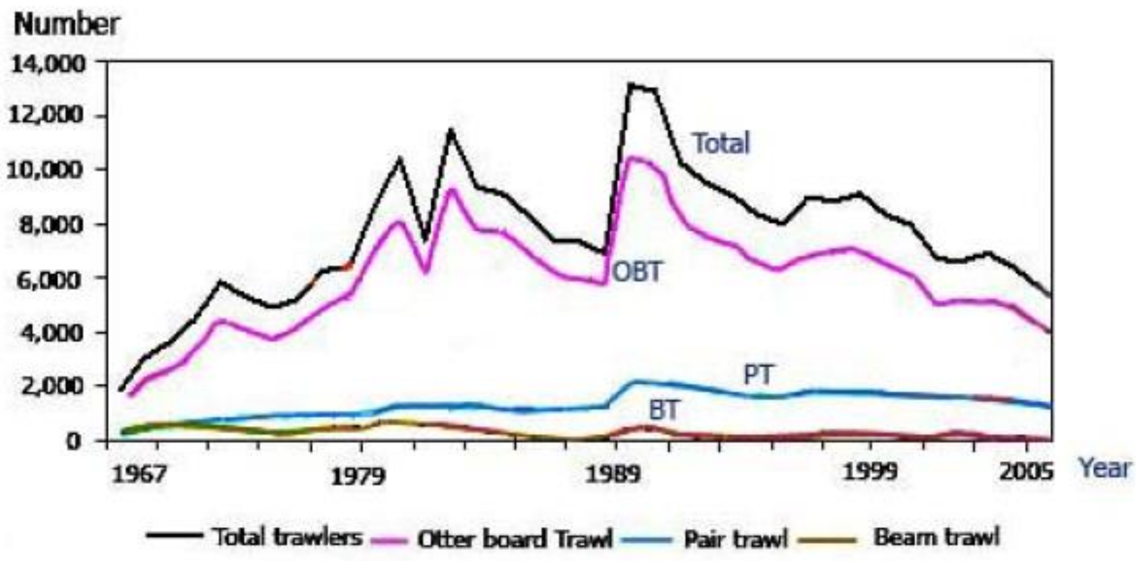


Fig. 13. Changes in types of trawler and overall trawl effort between 1967 and 2006. Thailand (Supongpan and Boonchuwong 2010)

Beam trawls have a relatively low proportion of trash-fish in the catch. From 1982 to 1997 the proportion of trash-fish decreased from 36 percent 0 percent. The non-penaeid prawns are the main species caught and these account for 71 percent of the total catch. Fishing grounds of beam trawl are in shallow waters with muddy bottom. This kind of fishing is very common in the south of Thailand such as Nakhon Sri Thammarat, Surat Thani, Chumporn but note this information is old and requires updating. There is no seasonal pattern and fishing is carried out throughout the year (http://map.seafdec.org/Monograph/Monograph_thailand/bt.php).

Otter trawls

Otter trawls are used to target fish, shrimp, Sergestid shrimps and jellyfish (Supongpan and Boonchuwong 2010). The mesh size used will vary according to the species sought, as will the area and time fished. Fish trawlers take a mix of demersal and pelagic species and the shrimp trawlers mainly take shrimp, other invertebrates and trash fish. Sergestid shrimp trawlers catch 95% shrimp and jellyfish trawlers only catch jellyfish.

Shrimp otter trawls operate from small fishing boats, 8-16 m in length and with low to medium engine power (30-120hp) (http://map.seafdec.org/Monograph/Monograph_thailand/bbt.php). They mostly operate from Nakhon Si Thammarat to Songkhla province, and the catches consist of shrimps and trash-fish. Shrimps are also the main target species of otter trawlers using booms (http://map.seafdec.org/Monograph/Monograph_thailand/bbtb.php) and these operate mainly in the inner Gulf of Thailand, from Trat to Chumporn province.

The fish otter trawls are the largest single fishery in Thailand. Ten to twenty men are needed for a fishing operation. The main catch are bottom fishes and trash-fish. The major fishing ports are Samut Prakan, Samut Sakhon, Songkhla and Phuket.

Pair trawling

Pair trawling (http://map.seafdec.org/Monograph/Monograph_thailand/bpt.php) was introduced in Thailand in the 1960s by Japanese fishermen. A pair trawl is usually operated in the day-time. Fishing grounds are in the Gulf of Thailand and the Andaman Sea at water depths down to 40 meters. Most catches consist of trash fish, squid, cuttlefish and threadfin bream.

3.2.2. Vietnam

Trawlers, in general, are one of the most important types of fishing gear in Vietnam (http://www.fao.org/fi/oldsite/FCP/en/vnm/profile.htm) and produced about 40% of the total catch (in 1997) (Son and Thuoc 2003, http://map.seafdec.org/Monograph/Monograph_vietnam/trawl.php). According to Nguyen and Thi (2010) there was an estimated 16,400 trawlers operating in Vietnam in 2008 and this increased to 20,340 units in 2016 of which 8,489 are listed as otter trawlers, 9,153 listed as pair trawlers and 2,698 units were identified as "trawlers" (Thong Nguyen pers. comm.). Trawls have been used in Vietnam for a long time and in the early years fishermen used two sailing boats to drag one trawl. The nets were made of cotton and the buoys were made of wood. The fishing grounds were mainly coastal areas with depths of less than 20 m.

As with other countries in the region the industrial development of the trawl sector was facilitated via foreign aid. In 1957, with the technical assistance of the Democratic Republic of Germany, four trawlers of 90 horsepower (HP) were used in the Gulf of Tonkin. In 1958, the People's Republic of China supplied Vietnam with 15 steel hulled otter-board trawlers each about 28m long and with an engine capacity of 250 Hp. In 1976, Norway provided Vietnam with four steel-hulled otter-board trawlers of 600 HP each. High opening trawl nets were used in these vessels for fishing in the Gulf of Tonkin. This pattern of an increasing number of vessels, increasing horsepower per vessel and better nets set the pace for ongoing development in subsequent years.

In Vietnam the number of trawlers in 1997 was 18,240, in 2007, 22,094 and in 2008, 24,091 (Nguyen and Thi 2010) and 22,554 in 2010 (Funge Smith et al 2012) (Table 4), with 20,340 in 2016 (see above).

In Vietnam the overfishing of inshore areas has resulted in fishing effort being shifted offshore and this has created a demand for larger vessels. Thus, even though the number of vessels may have declined, the overall fishing capacity may not have declined, or even increased. There has also been a shift from otter trawls into pair trawls possibly as a result of a simple depletion of demersal resources or because productivity has shifted from the demersal component of the ecosystem to the pelagic as a result of the overfishing (Hutchings and Baum 2005, Link et al 2002, Caddy and Garibaldi 2000).

Table 4. Number of trawlers by types and areas in Vietnam during 2007 – 2008. Source: Nguyen and Thi (2010)

Otter trawls	**Areas**	**2007**	**2008**
	The North	4,266	4,755
	The Center	3,207	2,666
	The Southeast	6,473	6,447
	The Southwest	3,631	2,558
	Sub-total	***17,577***	***16,426***
Pair trawls	The North	915	976
	The Center	934	2,419
	The Southeast	810	2,489
	The Southwest	1,858	1,781
	Sub-total	***4,517***	***7,665***
Total:		**22,094**	**24,091**

This is illustrated for Kien Giang province in Vietnam (Figs. 14 and 15) where the shift into pair trawling and the overall increase in the power of the boats has been well documented. Figure 14 documents the decline in the number of otter trawlers in the period 2005 to 2014 in the southern Vietnam province of Kien Giang and the increase in the number of pair trawlers (Nguyen et al 2015). Figure 15 shows how the percentage of pair trawlers with a horsepower rating >400 is far higher at 80% as compared to otter trawlers where only about 13% have engines of 400 horsepower or above. In part this may be related to the higher towing speeds of the pair trawlers, it may be that pair trawlers fish further offshore (as part of a government policy push to move fishing effort offshore) or it could relate to the fact that there remains a fleet of small shrimp vessels located inshore.

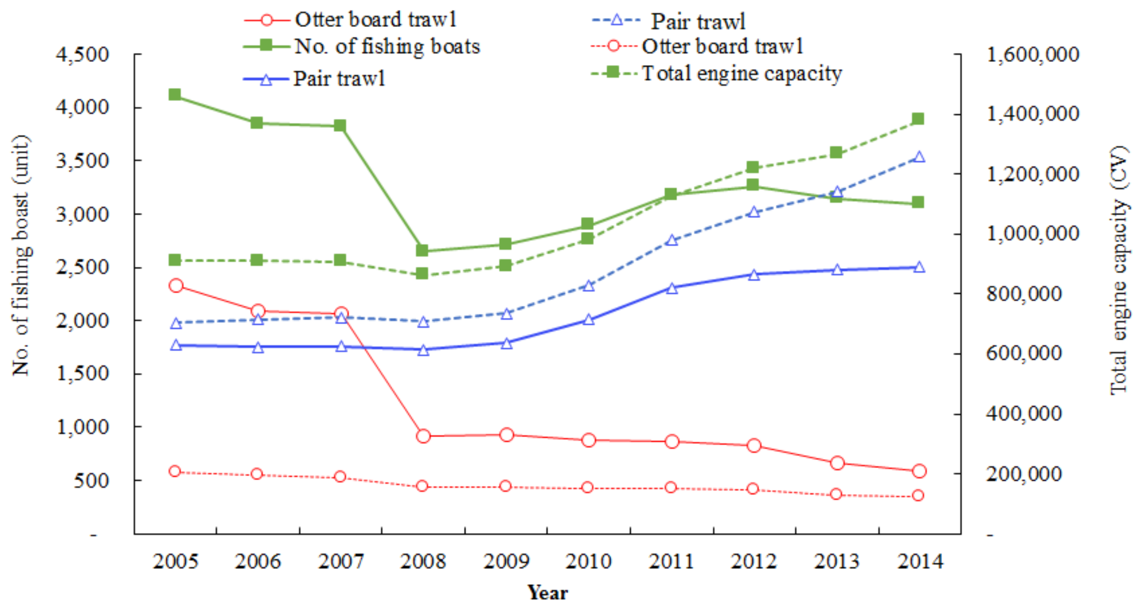


Figure 14. Change in the number of trawlers (solid lines) and engine capacity (dashed lines) Vietnam

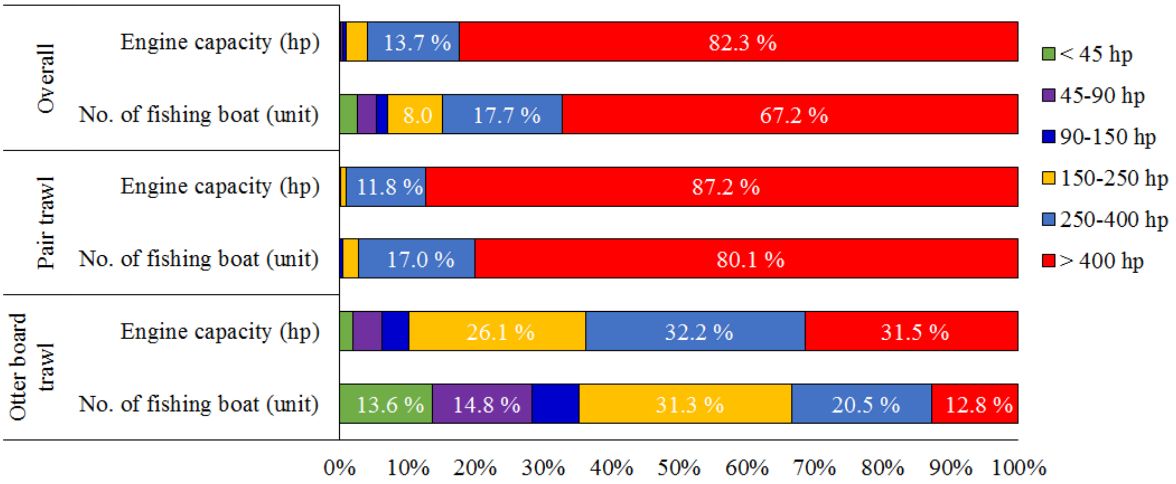


Figure 15. Distribution of engine capacity amongst trawlers in Kien Giang Province, Vietnam

Otter trawls

Otter board trawls for fish and shrimp are in widespread use in Vietnam as the large areas of continental shelf with soft sediments make trawling a viable fishing technique (http://map.seafdec.org/Monograph/Monograph_vietnam/trawl_bpt.php, http://map.seafdec.org/Monograph/Monograph_vietnam/trawl_bbt.php). Otter board trawls with booms have also increased in popularity as a mechanism for increasing the area swept by the nets (http://map.seafdec.org/Monograph/Monograph_vietnam/trawl_bbtb.php) and are not very different to an ordinary otter board trawl. The mesh size of the net for catching shrimp is 35 - 50 mm in the wings and in the cod-end is 20 - 25 mm. To catch demersal fish and other species the mesh size is bigger with the mesh size of the wings ranging 80-240 mm with 30-40 mm at the cod-end.

Pair trawling

Due to a decline in fish stocks and because the towing speeds of otter board trawlers are slow (and thus miss many species of fish) the numbers of otter board trawlers have decreased year by year. Bottom pair trawls are gradually replacing the otter board trawls for exploitation of fish and are very popular in the northern and southern regions. Most pair trawlers have engines of 200-450 HP per boat. There are two types of trawl used; an ordinary trawl, and the Chinese trawl with a very big mesh size.

Beam trawls

Beam trawls are mainly used for catching shrimp, so the mesh size is usually small (http://map.seafdec.org/Monograph/Monograph_vietnam/trawl_bt.php). The most common vessels are of a small size, with engines ranging from 22 to 90 horsepower, rarely up to Hp. They generally tow one or two nets but if they use the Chinese trawling method, one big boat can pull up to 18 nets.

3.2.3 Philippines

The amount of shallow (i.e. continental shelf) ground suitable for trawling is very low in the Philippines and this helps explain the very small number of trawlers (in comparison to other counries facing the South China Sea). According to Ramiscal and Dickson (2010) the number of registered trawlers was 398 out of a total 3874 registered commercial fishing vessels.

Catching stocks of demersal fish in commercial quantities in the Philippines using trawls became popular after the liberation period (1945-1946) (http://map.seafdec.org/Monograph/Monograph_philippines/Trawl.php). For the first three years fishermen used beam trawls but they subsequently shifted to use otter boards to increase the opening of their nets and this also resulted in many improvements in trawl design, construction and operation.

With the introduction of twin engines on trawlers in 1958 the trawling speed was increased to catch fast swimming fish. Filipino fishermen continued to modify their trawl nets to create a higher vertical opening to catch fish swimming higher in the water column. With the expansion of fishing operations to rough (uneven) grounds, plastic roller bobbins and oval boards were tried. The bobbin operations were considered successful in rough grounds as they could harvest big groupers and snappers.

With the desire of fishermen to catch more semi-pelagic fish, further net modifications were introduced into the trawling industry. For example, larger mesh sizes in the wings and at the entrance to the net enable faster towing speeds but still herd the fish into the smaller mesh sizes at the back of the net. In 1992, the bottom pair trawl was introduced by Chinese fishermen under a joint venture agreement (http://map.seafdec.org/Monograph/Monograph_philippines/Trawl.php). Pair trawling enables faster towing speeds to catch fish that would normally escape a single engine otter trawler.

According to Ramiscal and Dickson (2010) trawling is not a major gear type in the Philippines, comprising only about 10% of registered fishing vessels. This is probably due to the relatively small amount of trawlable ground in comparison to Thailand, China and Vietnam. The management regime distinguishes between 'municipal' vessels which are mainly small scale, inshore vessels of all types (including trawlers) and 'commercial' vessels which are the offshore vessels. For the commercial fleet the small trawlers dominate numbers (over 50% in 2007) with most vessels being less than 50 Gross Registered Tonnes (GRT). Fuel costs have had a big impact on the number of trawlers and this has driven a shift to Danish seining which does not require towing of the net and is thus cheaper to operate and has a lower impact on the seabed.

Beam trawls

Before World War II, Japanese beam trawlers numbering from 40 to 50 units were already operating the so-called "*utase*" in Manila Bay (http://map.seafdec.org/Monograph/Monograph_philippines/trawl_3.php). However, the use of the beam trawl did not last long after the introduction of the otter trawl. By 1950, the otter trawl replaced the beam trawl.

The beam trawl is now not used by the commercial fisheries sector but is used by inshore (municipal fishermen). The gear is operated in shallow sandy-muddy bottom waters by an outriggered motorized *banca*. Target species are shrimps, crabs, and small demersal fish. The fishing grounds of the beam trawl are shallow waters with a sandy-muddy bottom. Target species are shrimp, crab and small demersal fish.

Otter trawls

The otter trawl is the most effective fishing gear for catching demersal species in muddy-sandy bottom conditions but it also contributes some pelagic species such as sardines, mackerels, scad and anchovies which indicate the uses of a high mouth opening of the gear. It is used both by the municipal and commercial sectors (http://map.seafdec.org/Monograph/Monograph_philippines/trawl_1.php).

The otter trawl is classified into three types depending on the size of boat, namely; baby trawl (less than 3 GT), medium-sized trawl (3 GT - 20 GT), and Launch type trawl (greater than 20 GT). All three types use otter boards to open the net mouth.

Baby trawls are operated by outriggered motorized *bancas* 7 to 10 m long and powered by small (16 HP) petrol engines. They fish in municipal waters at depths from 5 m to 15 m targeting shrimps, fish and other invertebrates. The number of small (commonly unregistered) trawlers can be significant as set out in Ramiscal and Dickson (2010) for one fishing ground:

> *The Samar Sea and Maqueda Bay are important fishing grounds for both municipal and commercial trawls. There were 73 small commercial trawlers, 66 large municipal and 266 baby trawlers in selected areas during the rapid survey conducted in connection with the preparation of this paper. [Period roughly 2010-2011]*

The medium-sized trawl nets are also operated by larger outriggered *bancas*. Many net designs are used by the fishermen and the fish caught during daytime are slipmouths, hairtail, squid, and squilla. These trawl nets are mostly operated in Manila Bay, the Visayan Sea, the Samar Sea and Carigara Bay.

The launch-type trawl net is primarily used to capture demersal and semi-pelagic species. In the Lingayen Gulf, trawlers operate their nets at depths from 50 to 80 m. Species caught are slipmouths, hairtail, caranx, goatfish and nemipterids. In Manila Bay, trawlers operate near the Batanna and Corregidor coastal areas at depths from 30 to 60 m. Major species in the area are rastrelliger, anchovy, hairtail, squid, slipmouth, and croaker. In the Visayas area, trawls are primarily used to catch demersal and semi-pelagic species. Major species caught are nemipterids, hairtail, caranx, pompret, goatfish, lizardfish and other demersal species.

Pair trawling

For bottom pair trawling, the dominant species in northern Palawan are hairtail, red-eyed fish, lizardfish, sharks and goatfish (http://map.seafdec.org/Monograph/Monograph_philippines/trawl_2.php). In comparison to Vietnam it was believed that long term operations would not be viable as the maintenance and operating expenses will be doubled compared to a single-boat bottom trawl.

3.2.4 Malaysia

In Malaysia, since the scope of this study is the ECS and SCS only the states surrounding the SCS in Malaysia are included in discussions of the country, including Kelantan, Terengganu, Pahang, Johor, Sarawak and Sabah (Malaysian states near SCS; MSSCS). In these areas the number of trawlers fluctuated between 2900 and 3300 during 2005 – 2016, but a general increasing trend was observed during 2005 to 2010, decreasing afterwards. The proportion of trawlers among all fishing vessels, however, decreased continuously from 15.0% in 2005 to 9.3% in 2016 (Fig. 16). Landing volumes from trawlers declined gradually from 352 thousand tonnes in 2006 to 289 thousand tonnes in 2016 while overall landings increased. Trawling contributed around 40 – 50% of total capture fisheries production in the MSSCS (Fig. 17).

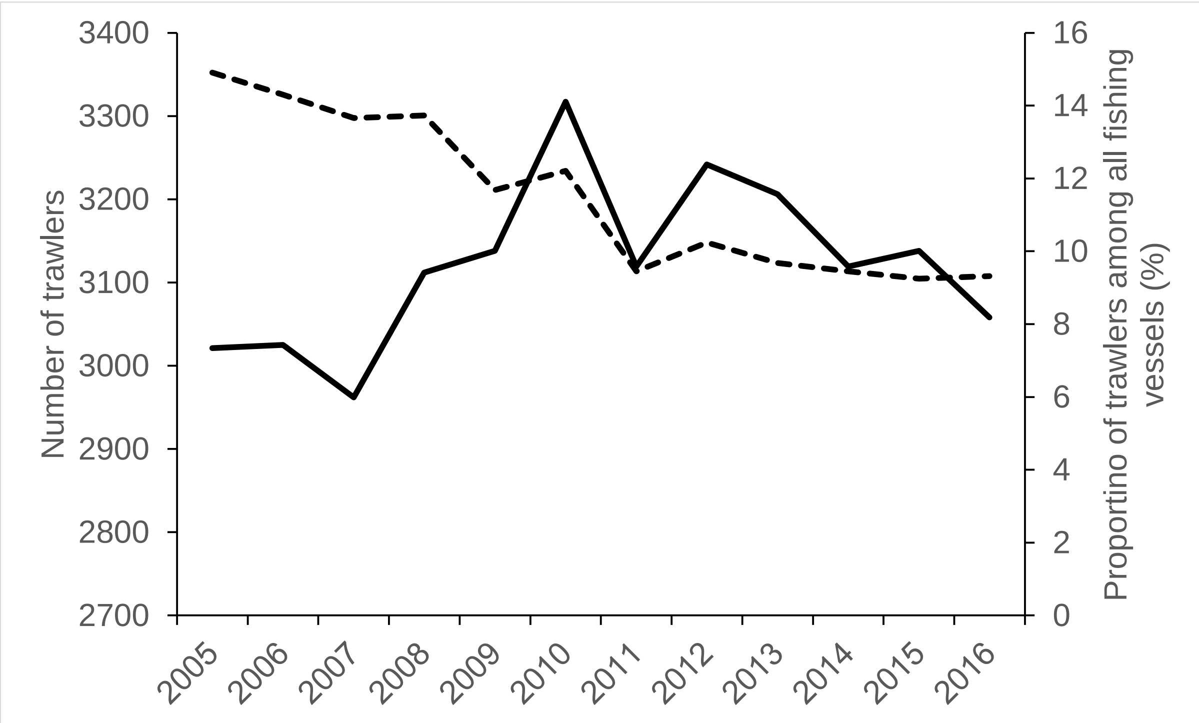


Fig. 16. Number of trawlers (solid line) and proportion of trawlers among all fishing vessels (dotted line) in MSSCS during 2005 – 2016 (Department of Fisheries, Malaysia)

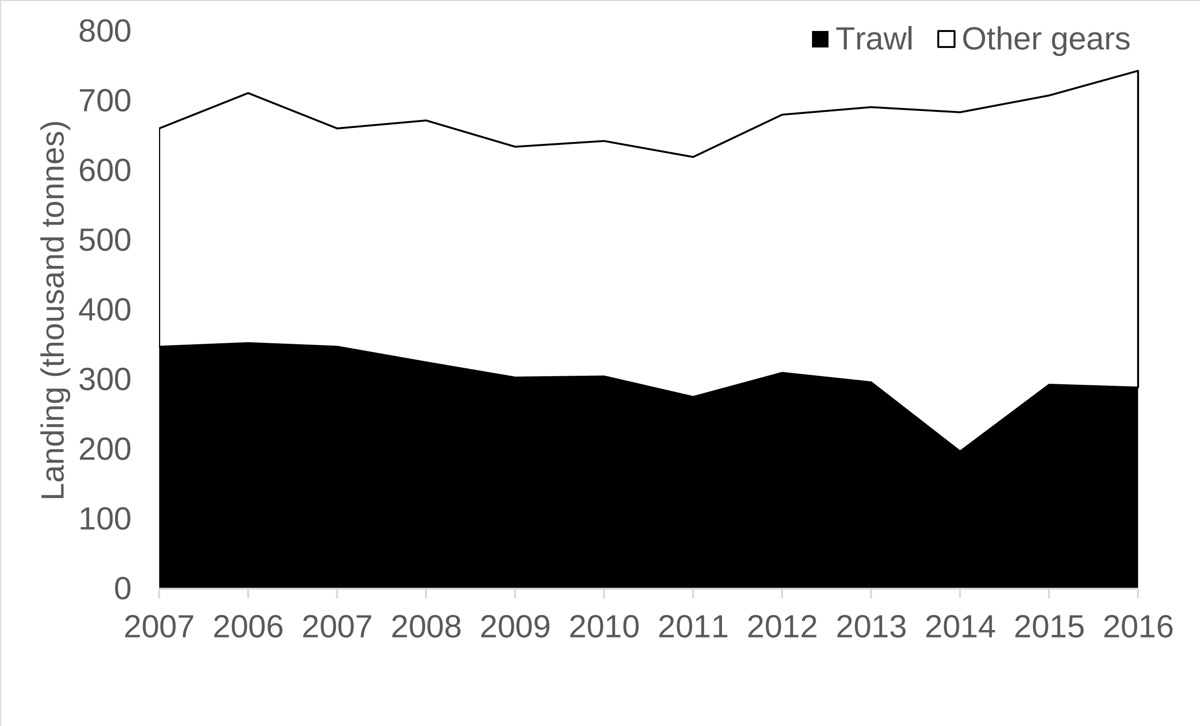


Fig. 17. The production of capture fisheries from trawling (shaded area) and other gear types (open area) in the MSSCS during 2006 – 2016 (Department of Fisheries, Malaysia).

3.2.5 China

Trawler numbers in the preceding country sections are dwarfed by the vessel numbers in China where the major fishing gears are trawls, various nets and hook and line.

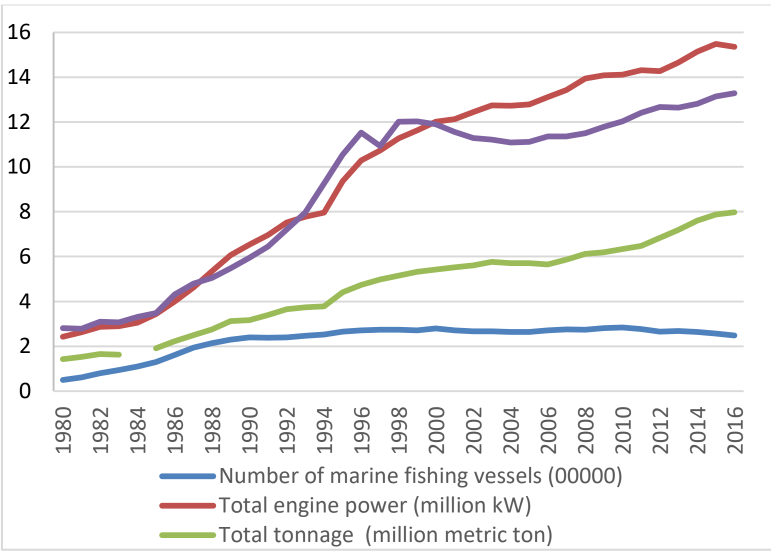


Fig. 18 China's marine capture fisheries production within its exclusive economic zone (EEZ), number of fishing vessels, total engine power and total tonnage of fishing vessels in 1980-2016 (Zhang et al., submitted). Most landings are taken by trawling.

Trawls make up just under a fifth of this fleet in terms of number of vessels and about 50% of the horsepower (Tables 5 and 6; Fig. 18). Hence trawlers are the single most important gear type overall in the country although their contribution to overall engine power has been declining over the last decade or so (Table 5) . In relation to the feed sector, trawlers accounted for about 3mmt out of the estimated 4.6 mmt according to a recent study (Greenpeace China 2017).

Table 5. Number and proportion of vessel by gear types in marine capture fisheries during 2007-2016 in China (Zhejiang, Fujian, Guangdong, Guangxi and Hainan) (China Fishery Statistics Yearbook)

	Trawl		Purse set		Gill net		Set net		Hook-and-line		Other		
	No. of vessel	% of total	No. of vessel	% of total	No. of vessel	% of total	No. of vessel	% of total	No. of vessel	% of total	No. of vessel	% of total	Total
2007	28,345	20.48	6,787	4.9	60,700	43.86	15,827	11.44	9,450	6.83	17,286	12.49	138,395
2008	24,243	18.14	6,606	4.94	58,387	43.69	16,414	12.28	9,482	7.1	18,494	13.84	133,626
2009	23,184	16.5	6,920	4.93	65,780	46.82	16,376	11.66	9,884	7.04	18,344	13.06	140,488
2010	22,075	15.81	6,966	4.99	67,604	48.42	17,624	12.62	8,302	5.95	17,053	12.21	139,624
2011	21,376	15.59	6,918	5.04	70,045	51.07	14,742	10.75	8,079	5.89	15,988	11.66	137,148
2012	21,078	15.82	7,323	5.5	68,151	51.14	14,006	10.51	8,089	6.07	14,604	10.96	133,251
2013	21,112	15.75	7,634	5.7	69,421	51.8	13,161	9.82	8,123	6.06	14,562	10.87	134,013
2014	20,968	16.16	7,517	5.79	68,341	52.68	12,105	9.33	7,315	5.64	13,475	10.39	129,721
2015	20,868	16.61	7,216	5.74	67,107	53.4	10,734	8.54	7,241	5.76	12,503	9.95	125,669
2016	20,446	16.79	7,219	5.93	64,356	52.83	10,365	8.51	7,637	6.27	11,788	9.68	121,811

3.3 Areas fished and zone-based management, not including Marine Protected Areas (MPAs)

The areas fished by trawls are dependent on what is physically possible to trawl, known about the specific areas fished and how these vary over the course of a year or on a year-to-year basis. Whilst good spatial data are often thought of as being important from an enforcement perspective it is equally important from a biodiversity management perspective.

Adjacent to the shores of China, Vietnam and Thailand are large areas of continental shelf which not only are highly productive from a fisheries perspective but have depths where trawling is feasible with accessible technology (as opposed to deepwater trawling). In the Gulf of Thailand, for example, there are very few areas of rocky reefs and trawling is widely distributed, especially in the shallower waters (20-30 m depth).

Table 6. Engine power (kW) and proportion of total vessel by gear type in marine capture fisheries during 2007-2016 in China (Zhejiang, Fujian, Guangdong, Guangxi and Hainan). Greenpeace China 2017

	Trawl		Purse seine		Gill net		Set net		Hook-and-line		Other		
	Engine power (kW)	%	Engine power (kW)	%	Engine power (kW)	%	Engine power (kW)	%	Engine power (kW)	%	Engine power (kW)	%	Total
2007	4,764,730	53.4	487,859	5.5	1,800,328	20.2	752,419	8.43	472,578	5.29	650,178	7.28	8,928,092
2008	4,747,035	51.6	607,906	6.6	1,863,093	20.3	816,275	8.87	441,368	4.80	724,777	7.88	9,200,454
2009	4,722,395	51.3	669,420	7.3	1,930,530	21.0	809,975	8.80	441,859	4.80	631,451	6.86	9,205,630
2010	4,531,832	49.9	680,352	7.5	1,998,421	22.0	791,675	8.71	472,116	5.19	616,447	6.78	9,090,843
2011	4,482,946	48.7	700,439	7.6	2,080,790	22.6	792,506	8.61	540,549	5.87	612,492	6.65	9,209,722
2012	4,487,331	48.5	773,359	8.4	2,148,820	23.2	740,136	8.00	575,182	6.21	530,842	5.74	9,255,670
2013	4,581,351	48.4	822,725	8.7	2,211,826	23.3	674,686	7.13	621,713	6.57	551,047	5.82	9,463,348
2014	4,517,299	46.3	915,429	9.4	2,414,782	24.8	636,537	6.53	663,840	6.81	604,652	6.20	9,752,539
2015	4,535,738	46.0	969,356	9.8	2,473,384	25.1	600,701	6.10	644,769	6.54	631,462	6.41	9,855,410
2016	4,466,839	45.2	1,080,966	10.9	2,443,699	24.7	605,188	6.12	712,849	7.21	571,197	5.78	9,880,738

In Vietnam there are four main areas where trawling is a common fishing activity (Nguyen and Thi 2010) and these correspond to the areas where the continental shelf is widest (Fig. 19).

As has been found in many parts of the world (Anon 2002, Rinjsdorp et al 1998, Zhang et al 2016) the distribution of trawl effort is not uniform and it varies according to seasonal and inter-annual factors as well as fisher knowledge about which areas are commonly productive. Figure 20 shows how fishing effort (low, medium, high) varies and how the main areas for otter trawlers differ from the main areas for pelagic trawlers in south western Vietnam, at least for the period surveyed (Nguyen et al 2015).

As the use of VMS increases managers will have far more detailed information on which areas are and are not productive. Figure 21 below shows the distribution of trawl shots in the Strait of Malacca between Malaysia and Indonesia. Thailand has been trialing VMS for its fleets, as has Indonesia. Whilst mainly used for enforcement purposes at the moment this information could be used for assessing impacts on biodiversity (e.g. evaluating impacts on the benthos and overlaps with the distribution of species at risk) and thus facilitate planning towards mitigation of such impacts.

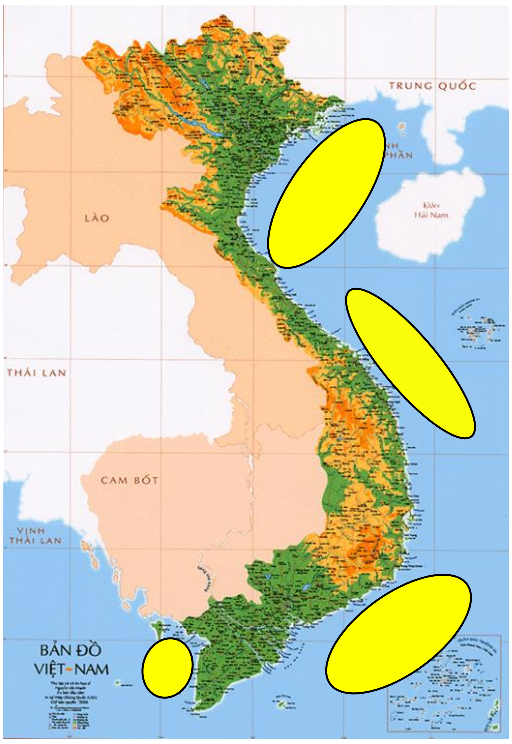


Fig. 19. Four main areas where trawling is a common fishing activity in Vietnam (Nguyen and Thi 2010)

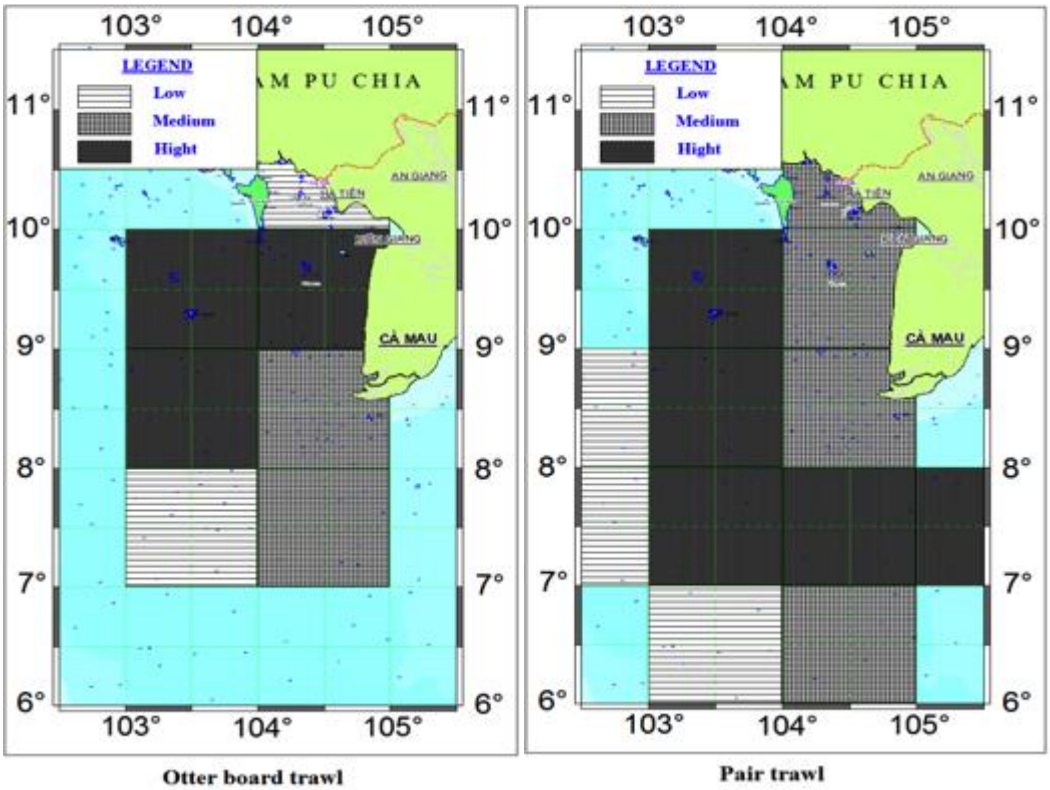


Fig. 20. Variation in fishing effort (low, medium, high) and by gear type for pelagic trawlers in south western Vietnam for the period surveyed (Nguyen et al 2015).

A recent study in the SCS using VMS tracking of Chinese trawlers provided useful information on area fished and fishing effort. The study was part of an effort to trace the origin of fish caught for traceability concerns over safety of aquatic products (Zhang et al., 2104).

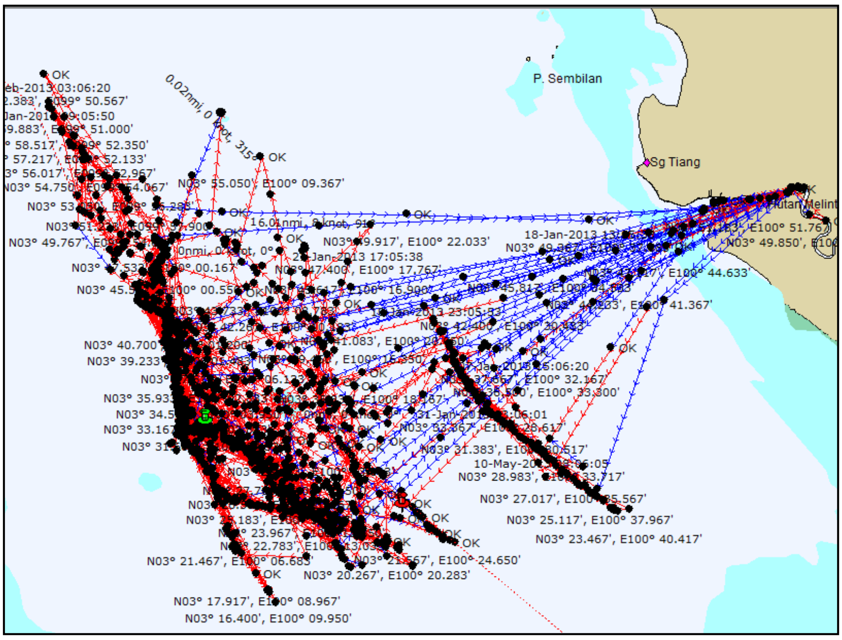


Fig. 21. Source: Department of Fisheries Malaysia 2013 – blue lines – travel to fishing grounds and red lines are trawl shots

The areas that are potentially fishable are also modified by various management rules, especially spatial closures (or zoning). Zoning is a common tool in Asia and is primarily used to separate user groups, especially the smaller scale fleets fishing closer to shore, from larger vessels that have the ability to fish further afield. Definitions of what comprises small versus scale vessels vary from country to country as do the boundaries between what is considered to be offshore and inshore. The 'inshore' areas are commonly fished by small scale operators using finer mesh nets for high value species such as shrimps but these areas are also commonly the areas where larger numbers of juvenile fish congregate. Country governments have increasingly sought to restrict trawls in these areas and encourage trawl effort to move 'offshore' where mesh sizes are required to be larger and the main species groups of interest are fish, not shrimp (e.g. Table 7).

In the case of Malaysia, entry of new inshore trawlers is prohibited since 1980 and permits for trawlers are now only issued for vessels larger than 70 gross register tonnage and operating more than 30 nautical miles from the shores (Fig. 22). A buy-back scheme for trawlers operating in Zone B was introduced in Kedah state irregularly. The Malaysian government also rejected the employment permit applications for foreigners working on trawlers operating in Zone B because these tend to have longer fishing hours. As of 2016 a trawl ban was implemented in Zone B and fishers were asked to switch their gears to purse seine.

*Table 7 Zone-based regulations relevant to trawlers (not including MPAs) (*SEAFDEC 2017; Zhang et al., submitted)

	'Inshore'		'Offshore'	
	Zone boundary	Vessel size limits	Zone boundary	Vessel size limits
Vietnam	Shoreline to 30m depth in Northern and Southern regions and to 50 m depth in Central region	Vessels with <40hp engine	From 30/50m depth to limit of EEZ	Vessels with >40hp engine
	'Inshore'		'Offshore'	
	Zone boundary	Vessel size limits	Zone boundary	Vessel size limits
Thailand	Shoreline to 12nm	Vessels of <5GT	12nm to limit of EEZ	Vessels >5GT
	'Inshore'		'Offshore'	
	Zone boundary	Vessel size limits	Zone boundary	Vessel size limits
Philippines	Shoreline to 15klm		15klm to limit of EEZ	
	'Inshore'			
	Zone boundary			
China	Seasonal blanket fishing moratorium; as of 2017 duration of 90-145 days, from 1st May			

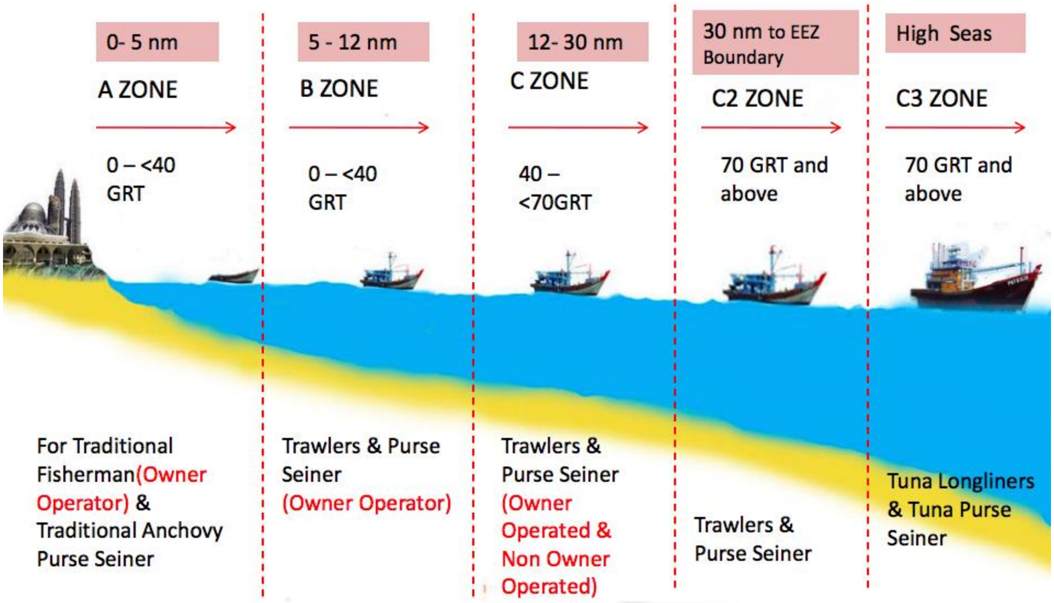


Fig. 22. Zoning system of Malaysian coastal waters for fisheries management (Nuruddiin and Isa 2013)

3.4 Employment in the trawl sector and dependent industries

According to Funge-Smith et al (2012) an estimated 3.73 million people were employed in the South China Sea fisheries (all gear types) in the years set out in Table 8. Distinguishing between full and part-time is difficult and reporting is inconsistent. Even though trawl catches represent about 50% of landings it is likely that this 3.73 million figure reflects more the large number of small, artisanal vessels than a substantial contribution by the trawl fleet. This figure does not include the employment in the processing sector which is likely to be dominated by products from the trawl fleets as many species taken are subject to value adding (see above). Whilst a workable estimate of the numbers of people dependent on the trawl fleets is probably impossible to generate, more than likely it is substantial.

Table 8. People employed in the South China Sea fisheries (all gear types) (Funge-Smith et al. 2012)

	Area					
	China *northern part of the South China Sea*	**Viet Nam**	**Philippines**	**Thailand** *Gulf of Thailand*	**Malaysia** *Peninsular Malaysia east coast,Sabah, Sarawak*	**Indonesia** *FMA 711*
Year	**2009**	**2003**	**2002**	**2000**	**2008**	**2010**
Full-time	376 716	750 000*			56 113	169 208
Part-time	272 083					150 811
Family member				80 857		75 036
Employee/crew				87 823		
National					44 364	
Foreign crew					11 749	
Small-scale			1 781 000			24 949
Commercial			7 800			
Total	**648 799**	**n/a**	**1 788 800**	**168 680**	**56 113**	**320 017**

Notes:

In Thailand, based on an average crew of 8 per beam trawler, 49 per pair trawler and 10 per otter board trawler, the number of people employed on fishing vessels was estimated to be 95,000 in 2006 (Supongpan and Boonchuwong 2010) and the number of people in the processing sector estimated at 330,000.

Based on average estimates for otter trawlers of 6 crew for small vessels (91-135hp) and up to 16 for large vessels (>450hp), and for pair trawlers, estimates range between 20 per vessel (Long 2003) and 49 per vessel (Nguyen and Thi 2010). Nguyen and Thi (2010) estimated that the total number of people employed on trawlers was about 102,000. It was estimated that the number of people employed in the post-harvest sector was in the vicinity of 388,000, the majority of which were women.

In Malaysia, the number of fishermen working on trawlers fluctuated between 13000 – 18000 during 2005 – 2016 and did not follow the increasing trend of the number of fishermen working on other fishing vessels (Fig. 23). The estimated number of fishermen per trawler was 4 – 5.

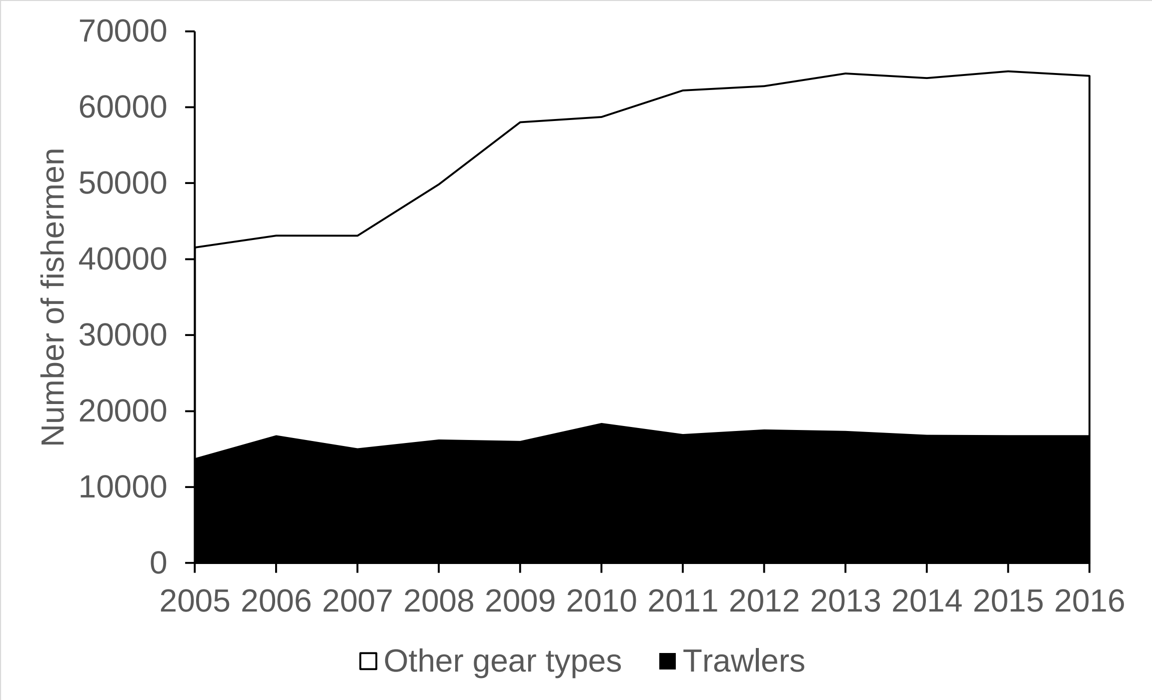


Fig. 23. Number of fishermen working on trawlers (shaded area) and other fishing vessels (open area) in MSSCS during 2005 – 2016 (Department of Fisheries, Malaysia).

In China, marine fisheries account for about 50% of the livelihoods among all major marine industries. These industries had 12.13 million people employed in 2014 of which 5.87 million livelihoods came from marine fisheries (Zhang et al., submitted).

The number of full-time fishermen involved in the capture fisheries of the SCS and ECS provinces in China (i.e. Zhejiang, Fujian, Guangdong, Guangxi and Hainan) increased from about 686,598 fishermen in 2008 to the peak of 737,317 in 2013, and then decreased to 665,400 in 2016 (Fig. 24; Ministry of Agriculture China, 2017).

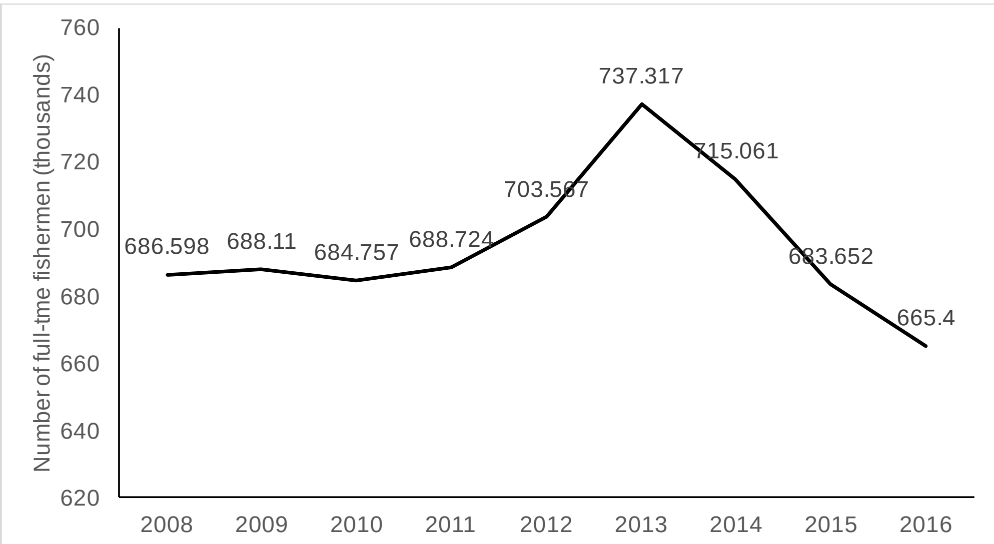


Fig. 24 Number of people full-time employed in marine capture fisheries in the SCS and ECS provinces in China (i.e. Zhejiang, Fujian, Guangdong, Guangxi and Hainan) (Ministry of Agriculture China, 2017).

4 SECTION 4

4.1 Relative importance of trash fish in trawler production

Volume of "trash fish" landed of a trawler is often substantial (Xiangzhi, Fuijian Province, April 2017).

4.1.1 Production volumes and types

The production from the trawl fisheries is so diverse in terms of species and products that obtaining a detailed understanding of the full reach of the output (landed catch, values and processed products) from these fisheries is difficult without conducting fishery by fishery evaluations. This diversity is further compounded by the patchy level of monitoring and reporting, although this is not confined to multi-species fisheries in the region.

In terms of the main product types derived from trawl catches the following is a list of broad categories covering both finfish and invertebrates:

1. Fresh, for direct food sale in domestic markets
2. Chilled and frozen for export
3. Preserved products for domestic and export markets – e.g. sauces and other fermented products, salted, smoked and dried products, including parts such as swim bladder.
4. Fish pastes and processed products like fish balls and surimi
5. Fish meal
6. 'Trash' fish which is the low-value mixed species catch used for animal feed. Note, however, that the term 'mixed fish' in some landings data can include both lower quality fish going for human consumption directly as well as for other uses.

"Trash fish" composition from a bottom trawler (Lingshui, Hainan, China April 2017).

Due to differences in the areas and times (seasons) fished as well as the gear type used the catch may be dominated by different suites of species which means that data sets that do not sample all year and all locations fished and specifying gear type used are likely to have some bias. This is particularly the case for inshore versus offshore fisheries and for demersal versus pelagic trawl fisherie. Some assumptions can be made, however. Generally the trawl catches are much higher than the catches of the non-trawl gears (see above) and it can be assumed that catches of some species are almost exclusively trawl-based, although some groups, such as shrimps and squid are caught in non-trawl gear. Data on species composition, sizes, and proportions from our field surveys conducted for the current study in Vietnam and China are also summarized (with full data provided in the Addendum I and II).

The diversity of trawl-derived products is reflected in the variety of processing plants. In Thailand, for example, there are large numbers of seafood processing plants producing a variety of products (Figure 25). Facilities for salting and drying products remain dominant and this undoubtedly reflects local tastes being the dominant market at a national and regional level.

Much of the output from these plants is aimed at regional markets where there is a demand for preserved (dried, salted, smoked and fermented) products. As in developed countries there are no requirements to document the type of fishing gear used to take the products used in the processing plants. The lack of information on gear type supplying materials and frequent lack of resolution of species composition involved does make it difficult to gain an understanding of the full value of these fisheries, their employment generation effects through the economy as well as possible environmental implications on the marine ecosystem.

Different qualities of fish from human food grade (top) to trashfish come in a range of container types and colours at Chinese ports, 2017

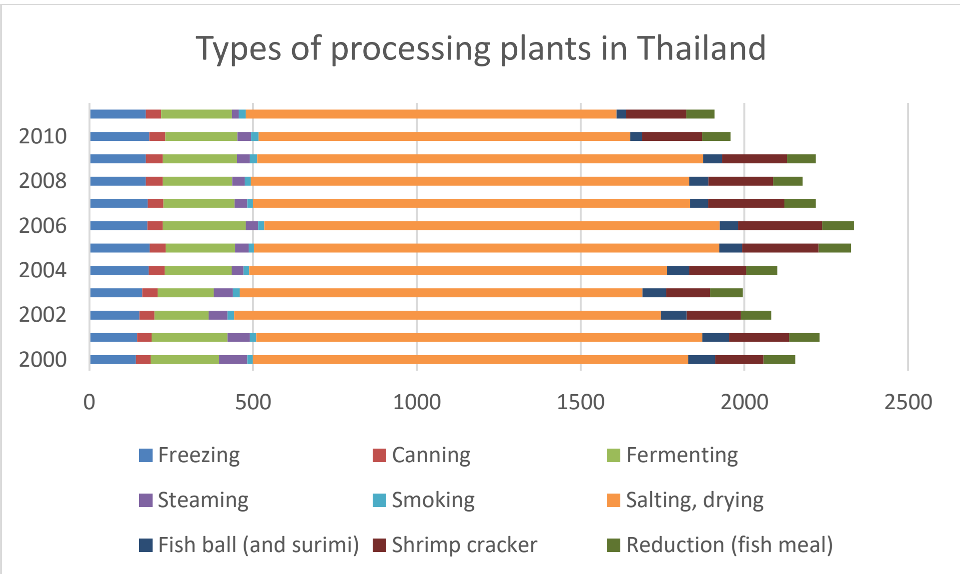


Fig. 25. Number of processing plants by category – 2000 to 2011 (Thai Year Books)

Availability of fish has a big influence on what pathways to market are utilised. There is a huge amount of variability driven by gear type, vessel size (which affects area fished fishing speed, and, commonly, mesh size), intraannual environmental factors such as the monsoons and interannual variability (e.g. Fig. 26). As mentioned by Edwards et al (2004) the dominant species differ on relatively large geographic scales in the country. For example the major trash fish species by area are anchovy (*Stolephorus* spp.) in the centre and southwest, lizard fish (*Saurida* spp.) in the north, centre and southeast and pony fish (*Leiognathus* spp.) in the centre and southwest.

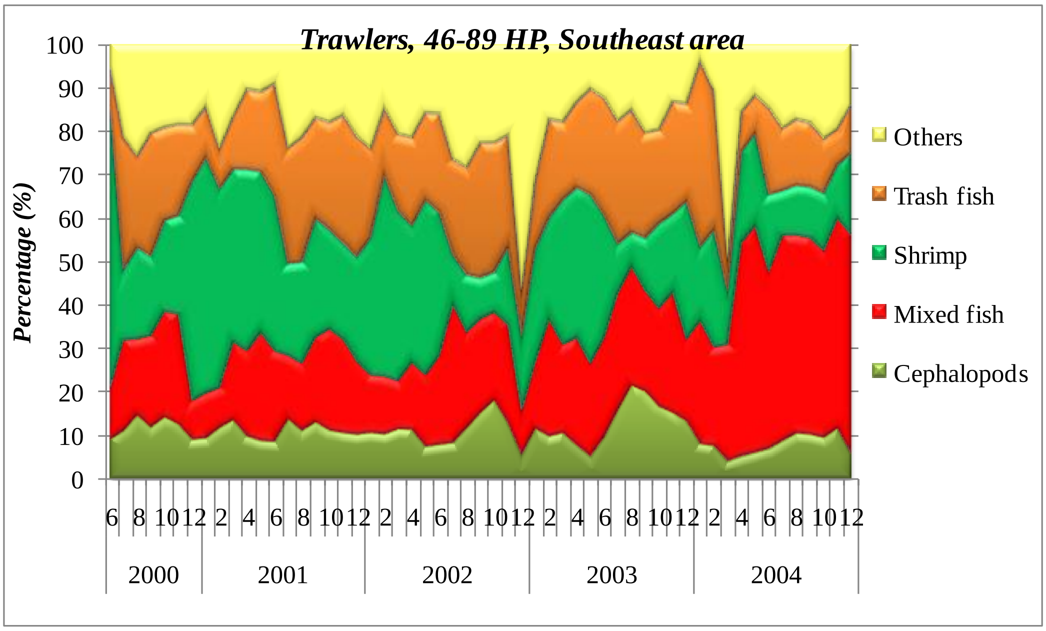


Fig. 26 Percentage of catch by month for trawlers (46-89hp capacity) off the south east coast of Vietnam -2000 to 2004 (Nguyen and Thi, 2010)

Layered over these shorter term and local variations are longer term changes such as the change in species and size mix driven by overfishing which has seen the larger species decline and be replaced by lower value fish and high value invertebrates (e.g squids and cuttlefishes) (Sommani 1987, Lundgren et al 2006).

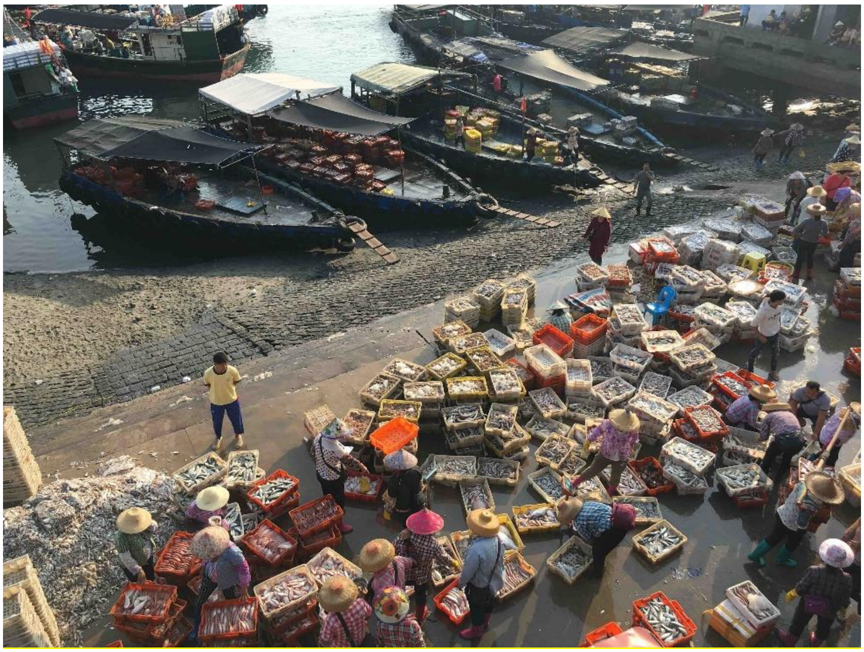
Fishery access policy changes have had a significant impact (e.g. Thai vessel access to the waters of adjacent countries, the trawl bans in Indonesia, the ongoing dispute over boundaries in the South China Sea). Myanmar, for example, has at various times banned Thai vessels from fishing in its waters (Butcher 2004) which has had a major impact on the viability of some some processing plants in Thailand. More recently, the Indonesian ban on trawling has also had a significant impact on the supply of raw material to Thailand (SEAFDEC 2017).

Overall, the processing sector has had to evolve to be flexible in the light of variability in supplies spatially and temporally (seasonal, annual and over time) as well as changes in demand (new products, e.g. the growth of surimi, higher quality demands, e.g. fish meal, different market requirements, e.g. western versus regional).

Trash fish being unloaded at a Chinese port, 2017

4.2 Fish and shellfish that may be for local consumption or chilled/frozen export and relative proportions of 'trash fish' in catches

At a regional (ASEAN) level the total volume of demersal fish species (food plus feed etc.) produced in 2014 was approximately 1,827,171 metric tons which represented about 11% of the total marine capture fisheries production of the Southeast Asian region (i.e. ASEAN plus other countries). Indonesia, produced some 1,081,482 metric tons or 59% of the region's total demersal fish production, followed by the Philippines with 296,651 metric tons (16%), Malaysia 275,322 metric tons (15%), and Thailand 173,369 metric tons (9%). Note that some countries with substantial trawl fisheries such as Vietnam and Myanmar do not report catches and China is not a part of ASEAN. These catches are variously described in terms of their use (e.g. trash, food; mixed fish could be for food or surimi), value (e.g. high value, trash) or taxon (at various levels of detail from species to order, or higher, or ecological such as 'forage'). Trash fish could be used for fishmeal or directly as animal feed. Large volumes of catch can be defined simply as 'other' or 'mixed fish' with no clear indication of what the catch is used for or its condition.



Landings of fish in China at two different docks; large volumes of trashfish are transported from larger trawlers on smaller boats to shore to be sorted on land, 2017

This section provides a general summary of different catch types with a focus mostly on trash and non-food fish, when information is available, but also considering major taxa taken. It then provides detailed taxonomic information from two field studies during which trawler catches were subsampled and identified to species levels (see also Appendix I Vietnam and Appendix II China) along with summaries of exisiting literature.

It is often difficult to distinguish between the different categories to separate food (direct for human use), and non-food (indirect such as for processing or for animal feed) uses, partly because this may depend on quality and local socio-economic factors, so the following sections only broadly summarize the major catches and their probable and various uses in different countries. In terms of catch composition by ASEAN countries Tables 10, 11 and 12 show breakdowns by taxon of fishes and invertebrates.

The snappers, groupers and some threadfins in better condition, taken by trawlers, would be used in the fresh/frozen food trade along with lower volume flatfishes, sillago species, emperor breams, sweetlips and spinefeet (Table 10). Other lower volume species such as the croakers, bigeye snappers (bigeyes), goatfishes and lizardfishes would often be used as feedstock in the surimi trade. Species such as ponyfish are either used locally via drying or are made into fish meal.

Trawler catches also take a diverse range of other species which may be sold directly as food if the quality is good enough or used as animal feed if quality is poor. Several shark and ray species are included within this diversity, often in juvenile form, an issue of concern given the significantly reduced shark populations in parts of the region.

Bamboo shark in amongs feed fish catch, China 2017.

Demersal trawl fisheries also catch large quantities of invertebrates, especially shrimps. Bearing in mind the above comments about trawl fisheries not being the only catching method for some species (especially swimming and mangrove crabs), Table 11 sets out the take (and value) of demersal invertebrates for those countries reporting data.

Table 10 Production of major groups of species of demersal fishes of SE Asian countries in 2014 by tonnes and value (US$ thousand) (SEAFDEC 2017)

Table 13. Production of major groups of species of demersal fishes of Southeast Asian countries in 2014 by quantity (metric tons) and value (US$ thousand)

Major groups of species	Country					Quantity (metric tons)	Value (US$ thousand)	Average value (US$/metric ton)
	Indonesia	Malaysia	Philippines	Singapore	Thailand			
Flounders, halibuts, soles	27,932	6,481	657	…	7,358	42,428	66,826	3,795
Catfishes	102,111	25,465	4,292	45	2,883	134,796	219,681	1,630
Lizardfishes	22,283	40,057	4,313	…	34,876	101,529	168,984	1,665
Groupers *nei*	110,418	10,296	18,924	29	…	139,667	393,624	2,820
Sillago-whitings	1,605	1,993	11,896	2	3,177	18,673	14,272	765
Bigeyes *nei*	51,399	17,136	…	…	35,849	104,384	116,047	1,110
Snappers	130,301	19,979	18,497	86	5,179	174,042	408,054	2,345
Fusiliers	94,487	500	19,874	3	…	114,864	127,949	1,115
Threadfins *nei*	128,393	64,021	41,798	42	51,649	285,903	544,336	1,905
Pony fishes	87,905	8,957	50,613	15	…	147,490	139,516	945
Drums and croakers	77,928	39,205	…	34	19,402	136,569	215,683	1,580
Sweetlips *nei*	20,503	4,380	…	22	…	24,905	39,930	1,605
Emperor breams	41,578	2,199	11,996	…	…	55,773	53,075	950
Goatfishes *nei*	82,659	18,069	27,380	14	…	160,952	160,952	1,600
Spinefeet *nei*	38,740	2,609	26,427	28	…	67,804	115,128	1,698
Others	63,240	13,975	59,984	27	12,996	177,602	104,643	589
Total	**1,081,482**	**275,322**	**296,651**	**347**	**173,369**	**1,827,171**	**2,982,826**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2014 (SEAFDEC, 2016a)*

Table 11 Production of major groups of crustaceans and mollucs of SE Asian countries in 2014 by tonnes and value (US$ thousand) (SEAFDEC 2017)

Major groups of species	Country						Quantity (metric tons)	Value (US$ thousand)	Average value (US$/ metric ton)
	Brunei Darussalam	Indonesia	Malaysia	Philippines	Singapore	Thailand			
Crustaceans	**187**	**361,290**	**121,929**	**62,503**	**350**	**81,381**	**627,640**	**1,692,542**	
Blue swimming crab	...	52,488	...	27,253	...	26,635	106,376	297,175	2,795
Indo-Pacific swamp crab	...	34,213	...	1,272	21	1,964	37,470	100,540	2,685
Lobsters *nei*	...	10,086	819	213	5	1,156	12,279	66,894	5,450
Banana prawn	...	89,606	...	...	...	9,506	99,112	304,518	3,070
Giant tiger prawn	...	34,784	...	645	...	1,545	36,974	142,515	3,845
Penaeid shrimps *nei*	...	...	...	9,530	...	20,209	29,739	51,965	1,745
Metapenaeus shrimps *nei*	...	40,169	39,682	23,590	...	15,998	119,439	279,558	2,340
Marine crustaceans *nei*	187	99,944	81,428	...	324	4,368	186,251	449,377	2,415
Mollusks	**93**	**112,234**	**88,856**	**61,252**	**71**	**128,616**	**391,122**	**1,026,756**	
Cuttlefishes *nei*	...	17,930	24,533	1,321	32	23,716	67,532	166,367	2,465
Squids *nei*	...	75,312	62,405	55,693	39	85,107	278,556	820,047	2,945
Octopuses *nei*	...	6,838	1,918	4,238		14,915	27,909	33,573	1,205
Marine mollusks *nei*	93	12,154	...	...	...	4,878	17,909	6,769	395
Total	**280**	**473,524**	**210,785**	**123,755**	**421**	**209,997**	**1,018,762**	**2,719,298**	

Source: Fishery Statistical Bulletin of Southeast Asia 2014 (SEAFDEC, 2016a)

Catches from pelagic/pair trawls are difficult to quantify as many of the species overlap with those produced in the purse seine sector. Small pelagics are a major contributor to the overall seafood supply and, in many countries, contribute substantially to food security. Considerable quantities are dried for local use, made into fish sauces (especially anchovies), canned for human consumption (and pet food) or used for fish meal. In Vietnam, for example, anchovies destined for fish meal are termed 'trash fish' which may simply reflect the view that anything destined for fish meal is termed trash fish or that it is only that portion of the catch which is unsuitable for human use (Table 12).

4.2.1 Indonesia

For top producer, Indonesia, the main demersal fish species were snappers contributing 12% to the country's total demersal fish production followed by threadfins *nei* at 11.8%, groupers at 10%, and catfishes at 9%. In terms of value, threadfin breams (*Nemipterus* spp. and *Polynemus* spp.) had the highest value at approximately US$ 544 million. Second were the snappers at US$ 408 million with major species that comprise mangrove red snapper (*Lutjanus argentimaculatus*) and snappers *nei* (*Lutjanus* spp.). Groupers *nei* came in third with groupers *nei* (*Epinephelus* spp.), chocolate hind (*Cephalopholis boenak*), leopard coral grouper (*Plectropomus leopardus*), and humpback grouper (*Cromileptes altivelis*) as the major species, at US$ 394 million.

Table 12 Production of major groups of pelagic fishes of SE Asian countries in 2014 by tonnes and value (US$ thousand) (SEAFDEC 2017)

Major groups of species	Country					Quantity (metric tons)	Value (US$ thousand)	Average value (US$/ metric ton)
	Indonesia	Malaysia	Philippines	Singapore	Thailand			
Scads	**638,248**	**193,159**	**397,572**	**32**	**68,082**	**1,297,093**	**1,758,904**	**1,355**
Scads *nei* (*Decapterus* spp.)	376,276	102,644	265,806	32	33,044	777,802	994,339	
Bigeye scad (*Selar crumenophthalmus*)	16,650	47,630	116,382	...	20,537	201,199	363,638	
Yellowstripe scad (*Selaroides leptolepis*)	199,674	13,816	...	...	...	213,490	254,334	
Hardtail scad (*Megalaspis cordyla*)	45,648	29,069	15,384	...	14,501	104,602	146,593	
Mackerel	**556,228**	**197,985**	**137,232**	**80**	**171,285**	**1,063,810**	**1,988,106**	**1,870**
Narrow-barred Spanish mackerel (*Scomberomorus commerson*)	165,808	...	16,914	...	...	182,722	426,629	
Seerfishes *nei* (*Scomberomorus* spp.)	35,417	16,609	...	62	9,091	61,179	139,621	
Scomber mackerels *nei* (*Scomber* spp.)	1,271	...	1,403	...	...	2,674	1,349	
Short mackerel (*Rastrelliger brachysoma*)	269,411	...	39,602	...	...	309,013	416,108	
Indian mackerel (*Rastrelliger kanagurta*)	84,321	...	79,313	...	45,258	208,892	248,001	
Other rastrelliger mackerel (*Rastrelliger* spp.)	...	181,376	...	18	116,936	298,330	756,398	
Sardines	**296,281**	**...**	**361,120**	**...**	**80,648**	**738,049**	**477,964**	**650**
Sardinellas *nei* (*Sardinella* spp.)	220,565	...	354,423	...	80,648	655,636	284,118	
Spotted sardinella (*Amblygaster sirm*)	46,578	...	...	...	...	46,578	32,230	
Rainbow sardinella (*Dussumieria acuta*)	29,138	...	6,697	...	...	35,835	26,275	
Anchovies	**199,226**	**24,836**	**71,855**	**...**	**133,592**	**429,510**	**466,825**	**1,085**
Stolephorus anchovies (*Stolephorus* spp.)	199,226	24,837	71,855	...	...	295,918	408,600	
Anchovies *nei* (Engraulidae)	...	...	...	...	133,592	133,592	58,225	
Total	**1,689,983**	**415,981**	**967,779**	**112**	**453,607**	**3,527,462**	**4,691,799**	

Source: *Fishery Statistical Bulletin of Southeast Asia 2014 (SEAFDEC, 2016a)*

Very little information could be found on Indonesia trawler catches and little was available on the supply of feed for Indonesian aquaculture operations. An attempt to sample in major ports during this study was not possible due to government sensitivities. According to the most recent FAO fishery profile for the country most (about 55%) fish caught (all gears combined) are consumed as food with the balance processed and consumed as dried and salted, smoked or fermented fish. There are about 10 000 small fish processing operations, generally using traditional methods. Less than 2 % of the catch is canned. The canneries utilize pelagic species, mostly oil sardines and skipjack. Some fish, mostly shrimp and tuna, are frozen and exported.Only a small proportion is converted into fish oil, fishmeal and silage, that is into products for animal feed or other usages. Production of fishmeal takes place mostly in conjunction with canning of fish (http://www.fao.org/fishery/facp/IDN/en- prepared between 2011 and 2014).

4.2.2 Thailand

The proportion of economic and trashfish varies from gear type to gear type and according to the size of vessel and over time (Supongpan and Boonchuwong 2010 – Table 13). The proportion of trash fish as a proportion of total catch in Thailand increased markedly between the 1960s and 1990s (Fig. 10).

Trawlers		1976-1981	1989-1993	2003-2005
OBT<14 m				
%Economic fish		51.8	47.5	50.0
% Trashfish		48.2	52.2	50.0
OBT 14-18 m				
%Economic fish		41.6	33.9	50.9
% Trashfish		58.4	66.1	49.1
PT				
%Economic fish		42.3	55.0	63.9
% Trashfish		57.7	45.0	36.1
Sources	Supongpan and Kongmuag (1976-1981)		Isara (1996)	Kongprom *et.al.*, 2008)

Table 13. Percentage of commercial economic fish and trash fish caught by trawlers in the Gulf of Thailand (Supongpan and Boonchuwong 2010). OBT=otter board trawl

There may also be differences within the Gulf of Thailand with Noranarttragoon (2014) finding that trashfish accounted for 42.15%, 45.56% and 54.44% for otter board trawl (<14m), otter board trawl (>14m) and pair trawl respectively in the provinces of Prachuap Khiri Khan and Chumphon. Lastly, there are also definitional issues associated with the term trashfish. The Thais distinguish between ‘true’ trash fish, which are species that are inedible versus other trashfish which are species that may have another economic use but for reasons of small size or poor quality are recategorised as trashfish.

In Thailand the two major fishery categories by weight were food fish and trash fish, the former declining more markedly than the latter between 2000 and 2014 (Fig. 27 below).

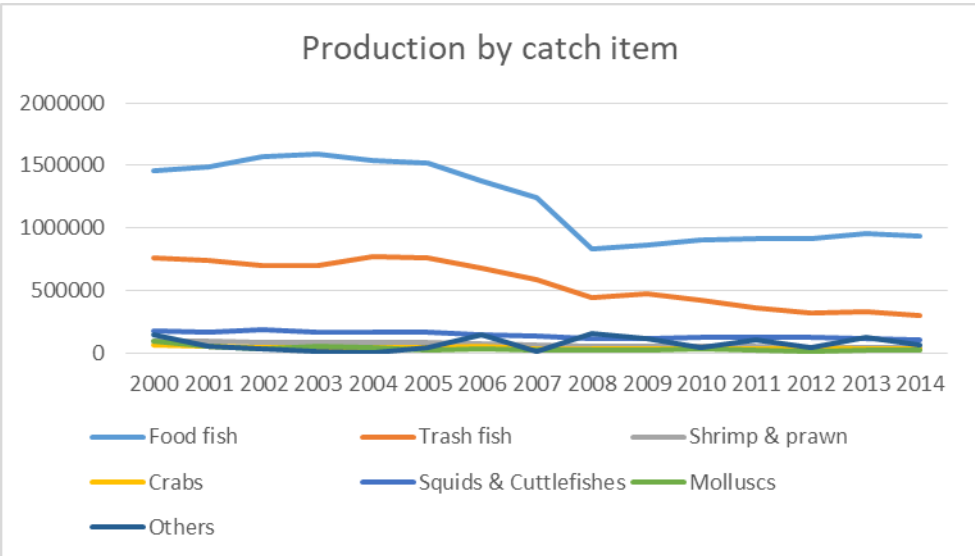


Fig. 27 Production of main seafood categories in Thailand (2000-2014) in tonnes (Thai Department of Fisheries Yearbooks)

A recent study on otter board trawl (OBT) and pair trawler (PT) catches from the west of the Gulf of Thailand for two trawler sizes provides some insight into species composition and catch characteristics. Data were collected from trawlers, i.e., small-sized otter board trawl (less than 14 m overall length; OBT1), medium-sized otter board trawl (14-18 m overall length; OBT2) and pair trawl (PT), during June 2013-May 2014 by catch sampling and interviews and data presented below (Noranarttragoon 2014). A distinction is made in Thailand between 'true' trash fish (species which are generally considered to be inedible) and other trash (juveniles, species that cannot be processed due to poor quality or volume excess). The same species can be used for human food or trash fish depending on size, location of landing and has varied over time according to changes in species composition and what is deemed to be better used as human food. Full species details are I the original report (Noranarttragoon 2014).

The average CPUE of small-sized otter board trawl (OBT1), medium-sized otter board trawl (OBT2) and pair trawl (PT) operating in Prachuap Khiri Khan and Chumphon Province were 48.21, 27.78 and 150.02 kg/hour respectively (Table 14). Trash fish showed a significantly high CPUE in every gear, particularly OBT1 and PT where over half the catch was made up of trash fish, 63.92% and 54.44% respectively.

Table 14 CPUE of commercial trawls (kg/hour) operated in Prachuap Khiri Khan and Chumphon Province during June 2013 - May 2104 (Noranarttragoon 2014).

Fleet	Average	Food fish	Trash fish
Small-sized otter board trawl (OBT1)	48.21	17.39 (36.08%)	30.82 (63.92%)
Medium-sized otter board trawl (OBT2)	27.78	16.07 (57.85%)	11.71 (42.15%)
Pair trawl (PT)	150.02	68.35 (45.56%)	81.67 (54.44%)

Species/group composition varied between different trawl gears. In the food fish group, demersal fish were the main component of OBT1 and OBT2 while pelagic fish were the main component of PT. In the trash fish group, the percentage of small-sized economic species was higher than true trash fish for every gear, i.e. 78.40%, 63.51% and 73.52% of OBT1, OBT2 and PT respectively (Table 15). In addition, cephalopods, along with shrimp and prawn were found in the trash fish group of all gears, but in lower percentages due to their higher economic value. These species can be sold as food fish at even a small size and get a higher price than if they were sold as trash fish. Species composition by gear in the categories of Food Fish and Trash Fish were as follows:

OBT1: - <u>Food fish</u>. Demersal fish made up the highest composition, followed by shrimp and prawn, and cephalopod, (74.14%, 11.70% and 8.43% of total food fish respectively) (Table 15). Flatheads and lattice monocle bream were the most common demersal fish while Penaeid shrimp was the most abundant shrimp. For the cephalopod group, cuttlefishes were found at a higher percentage compared to squids.

OBT1: -<u>Trash fish</u>. True trash fish represented 21.60% of the trash fish catch- the remaining 78.40% being made up of juveniles of economic species (Table 15). Juveniles of demersal fish species made up the highest composition, (62.49%) of total trash fish. Splendid ponyfish and spinefoots were the main demersal fish found in the trash fish catch. Invertebrates were also found but at a lower percentage, (11.35%) of total trash fish. Crabs, cuttlefishes and mantis shrimps were the main invertebrates found.

OBT2. - Food fish. Demersal fish made up the highest percentage, (61.87%), followed by cephalopods, (15.17%), shrimp and prawn, (9.19%), Pelagic fish were found less, (1.09% of total food fish) (Table 15). Flatheads, lizardfishes and threadfin breams made up more than half of the total demersal food fish catch. Cephalopods, squid and cuttlefish were found at a similar percentage to OBT1, (5% each). Scallops was also caught at 10.53% of the total food fish catch.

OBT2 - Trash fish. Most of trash fish caught by OBT2 were demersal fish and true trash fish (mainly ponyfish) represented 46.73% and 36.49% respectively (Table 15). Whereas pelagic fish, cephalopod, and shrimp and prawn were rarely found in the trash fish caught by OBT2. Flatheads, spinefoots and Indian halibut made up more than half of the total demersal trash fish catch. .

PT -Food fish. Pelagic fish and demersal fish were the major components, (46.64% and 35.89% of the total food fish respectively). Cephalopods made up 16.81% of catch (Table 15), a higher proportion than OBT1/2. Short mackerel were the main pelagic fish, then gold stripe sardinella and yellow striped scad, (15.39%, 9.48% and 9.39% respectively). Purple-spotted big eye and threadfin breams were the leading species of demersal fish. Squid was the most important cephalopod caught.

PT - Trash fish. About three fourths of trash fish were juveniles of economic species. Anchovies made up the highest composition, (23.61% of the total trash fish), while, ponyfish were the main group of true trash fish.

*Table 15 Catch composition of commercial trawls in Prachuap Kiri Khan and Chumphon Provinces June 2013 to May 2014. * Other invertebrate includes mantis shrimps, flathead lobster, crabs, shellfishes, etc*. (*Noranarttragoon 2014). OBT and PT are vessel types (see text above)*

Group	OBT1		OBT2		PT	
Food fish	% totalcatch	% food fish	% totalcatch	% food fish	% totalcatch	% food fish
Pelagic fish	0.61	1.68	0.63	1.09	21.25	46.64
Demersal fish	26.75	74.14	35.79	61.87	16.35	35.89
Cephalopod	3.04	8.43	8.78	15.17	7.66	16.81
Shrimp & prawn	4.22	11.7	5.31	9.19	0.01	0.02
Other inverts*	1.46	4.05	7.34	12.68	0.29	0.64
Total Food	**36.08**	**100**	**57.85**	**100**	**45.56**	**100**
Trash fish	% totalcatch	% trash fish	% totalcatch	% trashfish	% totalcatch	% trashfish
Small pelagic fish	1.85	2.89	2.18	5.18	23.07	42.37
Small demersals	39.95	62.49	19.69	46.73	13.15	24.15
Small cephalopod	0.66	1.04	0.91	2.16	3.05	5.61
Small shrimp/prawn	0.4	0.63	1.08	2.55	0.6	1.11
Small other inverts	7.25	11.35	2.91	6.89	0.15	0.28
Total Small economic fauna	50.11	78.4	26.77	63.51	40.02	73.52
True trash fish	13.81	21.6	15.38	36.49	14.42	26.48
Total trash	**63.92**	**100**	**42.15**	**100**	**54.44**	**100**

4.2.3 Malaysia

Trawlers are the major supply of trash fish in MSSCS. The volume of "trash fish" (i.e. ikan baja") produced from trawlers decreased from 126,495 tonnes in 2007 to 97,269 tonnes in 2016; and the contribution of all "trash fish" from trawlers decreased from 97.1% in 2007 to 89.1% in 2016.

"Trash fish" is one of the major components in the trawlers' catches. During 2007 – 2016, "trash fish" (i.e. ikan baja) occupied 30.2% (S.D = 2.1%) on average, following commercial fish (i.e. likely used for direct human consumption) which contributed the largest proportion (52.8%; S.D. = 2.4%) . Other commercial catches such as cephalopods and crustaceans contributed 11.4% (S.D. = 0.9%) and 5.4% (S.D. = 0.9%) on average respectively.

The volume of "mixed fish" (i.e. ikan campur") produced from trawlers fluctuated in a relatively narrow range between 25,624 – 31,709 tonnes during 2007 – 2012, which were about 47.3% - 58.7% of the total "mixed fish" production, there was a sharp decrease in volume of production afterwards with a lowest record in 2015 at 13510 tonnes however the proportion from trawler in fact increased to 63.1% (Fig.29).

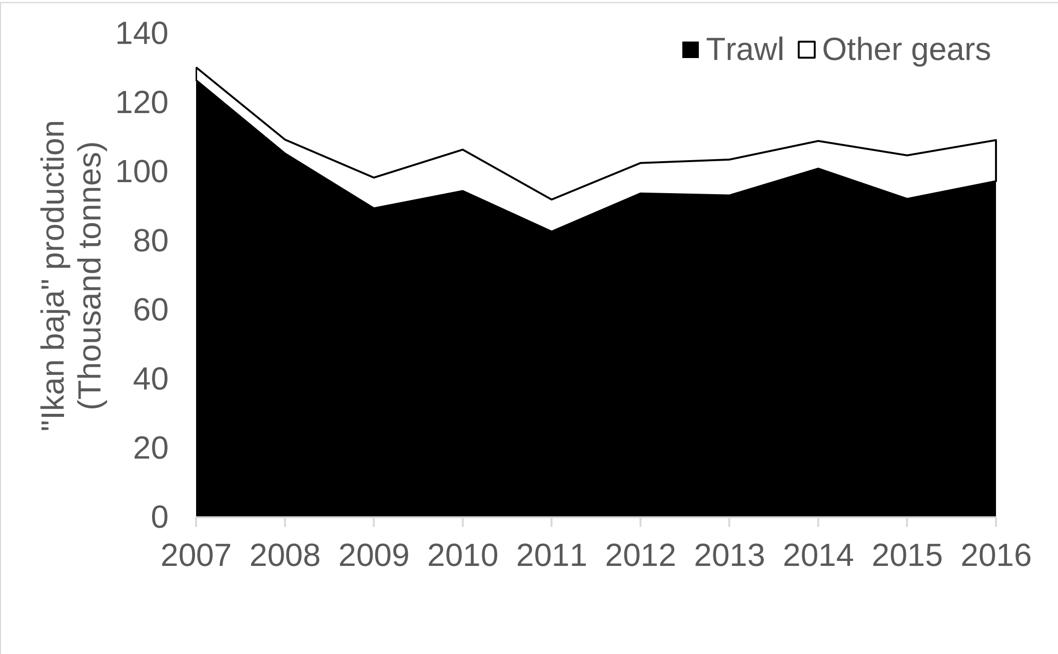


Fig. 28. Production of "Ikan baja" in MSSCS during 2007 – 2016 (Department of Fisheries, Malaysia).

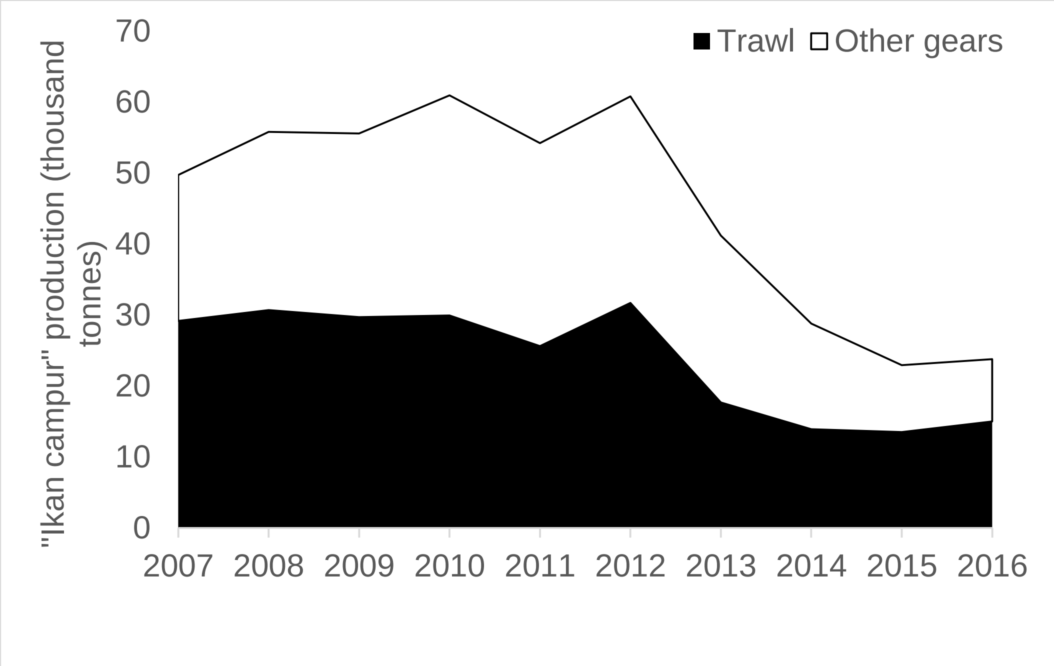


Fig. 29. Production of "Ikan campur" in MSSCS during 2007 – 2016 (Department of Fisheries, Malaysia).

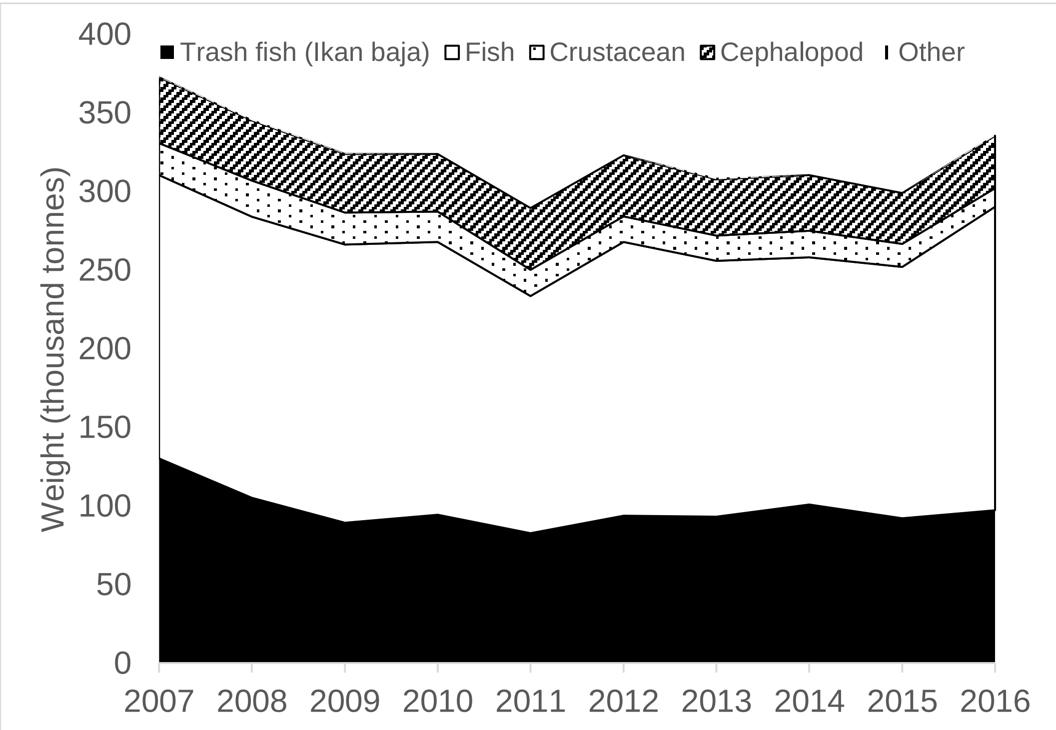


Fig. 30. Weight of different types of catches in trawlers from MSSCS during 2007 – 2016 (Department of Fisheries, Malaysia).

4.2.4 Case studies (Vietnam and China)

Specifically in relation to 'trash fish' destined for animal feed and its species composition, two field studies were conducted to provide more detailed information on this sector of the fishery. Most other available datasets do not specifically distinguish the details of this feed sector from other non direct human food uses of trawl catches. Hence we expand on two countries as specific case studies, both by covering available literature on this sector and then by summarizing our field data. Further details can be found on expanded Appendices (I-Vietnam; II-China).

Offloading trash fish from larger to smaller vessel (left) and packing trash fish in plastic bags (right) in Vietnam, 2017

1. Vietnam case study-literature and field study (also see Appendix I)

Literature - While data on fishery catch composition at the national level come in various forms and levels of detail, when there is sufficient resolution the data consistently indicate high volumes of 'trash fish' (note that in Vietnam this term is applied to anything that goes to fishmeal/feed whether it is in good condition or not). The pair trawlers get a lot of small pelagics like anchovies. This further illustrates why the term is confusing; for example pelagic fishes can also be referred to as forage fish). For example, the trash fish proportion in pair and otter trawl catches in a Vietnam province in 2014 was over 50% of the catch (Table 16). Seasonality was noted in trash fish catches of trawlers, being highest during April – June and October – December for otter trawlers and pair trawlers respectively (Table 17; see also Fig. 26). However, there is no clear definition in these reports of what actually constitutes "trash fish" and "mixed fish", just a statement that these two groups were juveniles of commercial species.

In another Vietnam study, observer data indicated that the proportion of "trash fish" varied by fishing depth, and also between the north and southeast of Vietnam (Dao et al., 2005). "Trash fish" consisted of about 70% of the landings in the north between the depth of 0 – 30m, while in the southeast the proportion ranged from 0 – 42.1% in an increasing trend by depth. In the otter trawlers operating in the shallow areas of southwestern Vietnam, the catch proportion comprised of "trash fish" showed a general increasing trend from 2000 to 2004 in vessels with engine power of

20-45 HP and 46 – 89 HP. Dao et al. (2005) estimated the annual landing volumes of "trash fish" in Vietnam to be between 300,000 and 600,000 tonnes in the period around 2005, and around 280,000 tonnes of these "trash fish" were used in fishmeal production. The study did not mention the use of the remaining part of the catches and there were no clear definitions of the groups of fishes involved in these catches.

Table 16. Total catch landings (tonnes) of commercial groups from trawl fisheries in Kien Giang Province, Vietnam, in 2014 (Nguyen et al. 2014).

	Otter trawl		Pair Trawl		Total	
Commercial group	Weight	%	Weight	%	Weight	%
"Trash fish"	8733	39.6	237576	56.3	246309	55.5
Mixed fish	3953	17.9	78286	18.5	82239	18.5
Sciaenidae	0	0.0	8994	2.1	8994	2.0
Batoidea	526	2.4	0	0.0	526	0.1
Nemipteridae	0	0.0	14845	3.5	14845	3.3
Synodontidae	0	0.0	7544	1.8	7544	1.7
Mullidae	508	2.3	0	0.0	508	0.1
Priacanthidae	0	0.0	6269	1.5	6269	1.4
Sepiida	257	1.2	5055	1.2	5312	1.2
Teuthida	0	0.0	31857	7.5	31857	7.2
Mixed cephalopods	793	3.6	26896	6.4	27689	6.2
Mixed shrimp	6139	27.8	0	0.0	6139	1.4
Penaeus semisulcatus	649	2.9	0	0.0	649	0.1
Others	488	2.2	4809	1.1	5297	1.2
Total	22046	100.0	422131	100.0	444177	100.0

A study specifically investigating the "trash fish" composition in Kien Giang province in the south of the country in 2014 found 135 and 93 species of fish from otter trawlers and pair trawlers respectively (Nguyen et al. 2014). The top five most abundant species by weight in "trash fish" from otter trawlers were *Lagocephalus lunaris* (7.4%), *Leiognathus brevirostris* (6.0%), *Upeneus tragula* (5.8%), *Mulloidichthys vanicolensis* (4.8%) and *Leiognathus lineolatus* (3.7%); while the top five in pair trawlers were *Encrasicholina heteroloba* (32.5%), *Stolephorus tri* (11.0%), *Stolephorus indicus* (7.9%), *Stolephorus commersonii* (3.8%), *Encrasicholina punctifer* (2.4%). Among the species found in "trash fish", 12 commercially important species were selected for length measurement, and the largest individual of 7 species were smaller than size at maturity, indicating all the individuals of the species in the "trash fish" were in the immature size range (Table 18).

Observer data from Dao et al. (2005) reported 2 – 6 species accounting for 70 – 90% of the "trash fish" by weight from the landings of pair trawlers in north and southeast Vietnam; pair trawlers catch more small pelagics because they tow faster.

Table 17. Catch composition of otter trawlers and pair trawlers in Kien Giang province in 2014 (Nguyen et al. 2014)

		Catch composition (%)			
	Commercial group	Apr - Jun	Jul – Sep	Oct - Dec	Average
Otter trawl	"Trash fish"	61.4	39	28.7	39.3
	Mixed fish	2.2	20.2	24	17.9
	Batoidea	11.1	0	0.1	2.5
	Mullidae	9.3	0	0.9	2.4
	Mixed cephalopods	1.9	5.5	2.6	3.4
	Sepiida	1.7	1.8	0.3	1.1
	Penaeus semisulcatus	4.7	1.4	3.5	3.1
	Mixed shrimp	5.1	29.7	38	28
	Others	2.5	2.4	1.9	2.2
Pair trawl	"Trash fish"	56.8	41.4	70.3	56.9
	Mixed fish	26.9	18.8	13.2	19.2
	Nemipteridae	3.1	6	1.4	3.4
	Synodontidae	1	3	1.1	1.7
	Sciaenidae	0.2	5.5	0	1.8
	Pricanthidae	1.1	2.8	0.4	1.4
	Teuthida	1.9	8.3	10.3	7.1
	Mixed cephalopods	7.8	10.5	1.5	6.3
	Sepiida	0.5	2	0.9	1.1
	Others	0.7	1.7	0.9	1.1

Table 18. Lengths of fish samples of 12 commercially important species in trash fish collected from Kien Giang, Vietnam from otter and pair trawlers and maturity length (n = 901) (Nguyen et al. 2014). Maturity size data were obtained from FishBase.

Family	**Species**	**n**	**Total length (cm)**				**Maturity length (TL; cm)**
			Min.	**Max.**	**Average**	**SD**	
Gobiidae	*Parachaeturichthys polynema*	83	4.7	7.5	6.3	0.6	7.5
Scombridae	*Rastrelliger brachysoma*	40	7.7	13.7	10.6	1.6	17.0
Scombridae	*Rastrelliger kanagurta*	106	6	14.1	10.3	2.5	19.9
Mullidae	*Mulloidichthys vanicolensis*	36	7.1	9.5	8.1	0.5	24.0
Synodontidae	*Saurida elongata*	38	6	10.6	8.6	1.3	25.0
Synodontidae	*Saurida tumbil*	21	5	10.3	7.4	1.2	30.0
Engraulidae	*Encrasicholina heteroloba*	269	4.3	7.5	5.6	0.7	6.0
Engraulidae	*Stolephorus indicus*	196	4.8	12.5	9.9	0.7	9.0
Engraulidae	*Stolephorus tri*	30	4.3	5.5	5	0.3	4.8
Mullidae	*Upeneus japonicus*	29	4	7.3	5.9	0.9	7.9
Mullidae	*Upeneus tragula*	20	3.4	6.7	4.7	1	12.5
Mullidae	*Upeneus sulphureus*	33	8	9.9	8.9	0.4	9.9

Field studies - From our own field studies to investigate catches in Vietnam from otter and pair trawlers (29 May to 13 June 2017), "trash fishes" of at least 1 kg were collected from randomly selected vessels to investigate species composition and size ranges of individuals caught; in total, 3 – 5 kg of samples were collected from each port (i.e. from 3 – 5 vessels). Additonal information on the proportion of "trash fish" in trawler catches was obtained from 10 vessels by fishermen interviews (50% stern(=otter) trawlers and 50% pair trawlers).The mean proportion (percentage) by weight of commercial fish in the bottom trawl catches, which includes those used for direct human consumption and raw materials for human food products, was 19.2% (S.D. = 13.3%) while the proportion of "trash fish" (=feed fish) was 79.9% (S.D. = 12.7%) (see Vietnam Appendix I for details). The majority of these samples (by weight) (95%) was comprised of fish (49.86 kg), while 1.958 kg (3.73%) and 0.67kg (1.28%) were crustaceans and cephalopods respectively (Table 19). Since "trash fish" were usually not well preserved, the condition of the specimens was sometimes not good enough for counting abundance and/or conducting length measurements, particularly for crustaceans and cephalopods. In total, 150 (59 families), 30 (8 families) and 5 (3 families) of fish, cephalopods and crustaceans respectively were identified from the "trash fish" samples collected (Table 20).

Fishers reported mesh size to be between 1 and 2.5 cm but the only mesh measured by this study on any vessel was 1 cm (stretched mesh), much smaller than the minimum allowable legal size limit of 2 cm.

This Information on the proportion of "trash fish" in trawler catches was obtained from 10 vessels by fishermen interviews (50% stern trawlers and 50% pair trawlers). The length and the engine power of these vessels ranged from 17 to 25 m and from 200 to 1005 HP. Eight of the vessels operated inshore areas near their home ports while the others did not report clearly on their fishing areas. The last fishing trip duration reported varied from half day to a month (mean = 6.05 days; sd = 9.6), mostly a few days in length. The duration of trawling in a haul is from 2-4 hours and the fishing trip may last from 1 to 3 weeks. The main catches are bottom fishes, semi-pelagic fishes and trash fish.

Table 19. Total weights of fishes, crustaceans and cephalopods in the samples collected in our field study

	North		Central		South		Total	
	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%
Fish	33131.2	98.57	2187.3	58.42	14537.4	96.10	49855.9	94.99
Crustacean	160.9	0.48	1499.1	40.04	297.4	1.97	1957.4	3.73
Cephalopod	320.2	0.95	57.9	1.55	293.1	1.94	671.2	1.28
Total	33612.3		3744.3		15127.9		52484.5	

Fishes: The top five species/groups of fish, many of which are pelagics, by biomass were *Rastrelliger kanagurta, Siganus canaliculatus, Sardinella gibbosa, Trachurus japonicus* and "Mixed unidentified fish" in descending order, contributing about 44% of the fish samples by weight (see Appendix I for full species list), and the top five species/groups of fish by abundance were *Siganus canaliculatus, Rastrelliger kanagurta, Bregmaceros japonicus, Sardinella* sp. and *Encrasicholina heteroloba* in descending order, comprising about half of the fish samples by abundance.

Table 20. Number of species and families identified in the catch samples in our field study. Cephalopods were recorded but not identified to family or species levels for specimens collected from Central and South Vietnam due to poor condition of the specimens.

	North		Central		South		Total	
	Family	Species	Family	Species	Family	Species	Family	Species
Fish	29	48	27	52	37	84	59	150
Crustacean	4	12	6	18	2	3	8	30
Cephalopod	3	5	*	*	*	*	3	5
Total	36	65	33	70	39	87	70	185

Specimens identified to species level were cross-checked with the IUCN Red List (Appendix I) and most (61; 41.1% of the fish species identified) have not been assessed for their conservation status. Fifty-six (37.1%) assessed species were listed as Least Concern and two listed as Data Deficient. Two species were considered to be threatened, *Scomberomorus commerson* (Near threatened) and *Evynnis cardinalis* (Endangered).

In all, 1136 individuals of complete (i.e. all specimens that could be measured in their lengths and identified) fishes were measured for their lengths, of which 868 individuals had length at maturity available; samples that could not be identified to species level or measured due to poor condition were not included in the maturity analysis. Samples collected from the north were not measured in length and thus not included in the maturity analysis. The proportion of juvenile fish was about 65.90% by abundance and 51.61% by weight in a subsample consisted of 30 randomly selected individuals of each species from the samples collected from Central and South regions of Vietnam (Table 21). Only individuals identified to species level and with the body length successfully measured were included. Samples collected from the north were not measured by length and thus not included in the maturity analysis.

Visits and interviews with the staff from fish processing plants indicated that the types of raw materials preferred for surimi and fishmeal are different in terms of target species composition, quality and storage methods. The raw materials for surimi production were generally larger fish, comprised of *Nemipterus* spp., *Saurida* spp., *Trachinocephalus* spp. and *Xyrichtys* spp., relatively fresher and covered with ice. The raw materials for fishmeal production were generally small, including rotting fishes with no particular dominant species, which were not suitable for direct human consumption or for further processing for human food.

Crustaceans: Most crustaceans were crushed when collected from the vessels, likely due to the compression when piled up in the vessel, during capture or at the landing site. As a result, 15.7% of the samples by weight could not be identified to any level of taxonomy.

The top five species/groups of crustacean by weight were *Charybdis variegata, Miyakella nepa, Portunus cf. argentatus, Oratosquillina interrupta* and *Charydbis cf. miles* in descending order, contributing more than one-fourth of the crustacean samples analyzed by weight (i.e. 44.37%) (Appendix I). None of the species have been assessed according to IUCN categories and criteria.

Table 21. Proportions of juvenile and adult fishes by (a) abundance (number) and (b) weight, in a subsample consisting of 30 randomly selected individuals of each species from samples collected from Central and South regions of Vietnam in this study. Only individuals identified to species level and with the body length successfully measured were included.

(a) By abundance (numbers)

	Central		South		Total	
	n	% by n	N	%	n	%
Juvenile	247	77.67	325	59.09	572	65.90
Adult	71	22.33	225	40.91	296	34.10
Total	318		550		868	

(b) By weight

	Central		South		Total	
	Weight	% by weight	Weight	% by weight	Weight	% by weight
Juvenile	819.8	75.63	4092.8	48.52	4912.6	51.61
Adult	264.2	24.37	4341.7	51.48	4605.9	48.39
Total	1084.0		8434.5		9518.5	

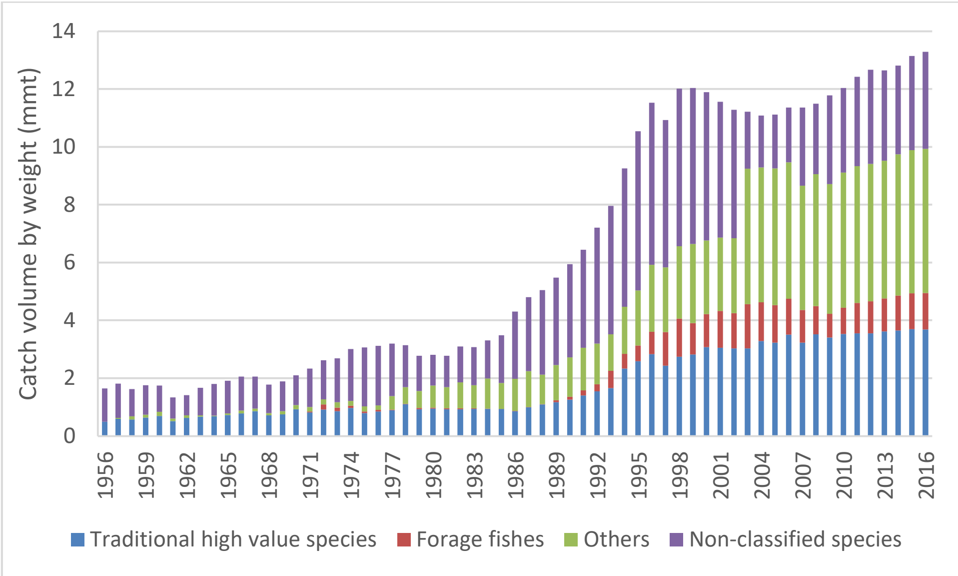
Cephalopods: Cephalopods could not be identified to species or family in the samples collected from the central and south regions because of bad condition of the samples. Five species of cephalopod were recorded from samples from the north, namely *Uroteuthis (Photololigo) duvaucelii, Cistopus indicus, Sepia pharaonis, Sepiella inermis* and *Sepioteuthis lessoniana* in descending order of biomass (Appendix I).

2. China case study-literature and field study

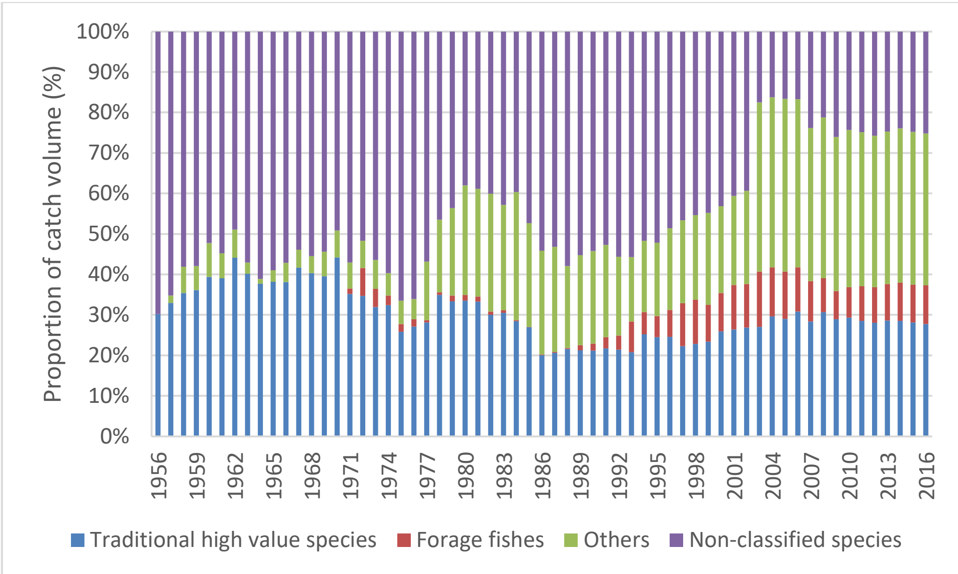
Literature – China produces more than one-third of the global fish supply, largely from its ever-expanding aquaculture sector which accounts for ~72% of its reported domestic fish production. China contributes >60% of global aquaculture volume and roughly half of global aquaculture value (Cao et al., 2015). The species cultured and which now use considerable quantities of fish feed and/or fish meal include a wide range of species but predominantly various carps, large yellow croaker, largemouth bass, snakehead, shrimps, etc. (Appendix II).

For China between 1956 and 2016, while catches of high value species increased, as did all catch categories, their relative proportion declined (Fig. 25).

The composition of China's marine catches over the past six decades has shifted from a small number of species of relatively high value to many smaller fishes of lower value. The shift has been from higher trophic level species such as largehead hairtail (*Trichiurus lepturus*) and large yellow croaker (*Larimichthys crocea*) which have declined due to overfishing (see stock assessments below) to a range of lower trophic level species or juveniles of higher trophic level species which are heavily used for fish feed or fishmeal rather than directly as human food (APFIC 2005, Zhang et al., submitted). Some of these smaller fishes were often discarded in the past but became more valuable as aquaculture, particularly mariculture grew, and the need for feed and fishmeal increased (Cheung and Sadovy 2005; Chau and Sadovy, 2005; Zhang et al., submitted).



(A)



(B)

Fig. 25. (A) Catch volume by weight of different categories in China's EEZ in 1956-2015 (million metric tonnes, mmt); (B) Percentage of catch of different categories in China's EEZ in 1956-2015 (Zhang et al. submitted)

The growth in trash fish usage has been particularly marked since the start of the current millennium (Fig 26). So called trashfish has been used in an unprocessed form for animal feeds at a household/smallholder level (e.g. duck food and unprocessed for fish food) and at an enterprise level (e.g. mink farming and fish farming – Greenpeace China 2107) for decades if not centuries (using non-trawl sources). Nowadays that feed use is high in the aquaculture sector; one recent study determined that 76% of China's aquaculture species require trash fish as feed (Greenpeace

2017). In 2014, aquaculture needed at least 7.17 million tons of China domestic marine fishery resources with another 5.09 million tons imported mainly as fishmeal or derived from unclear sources.

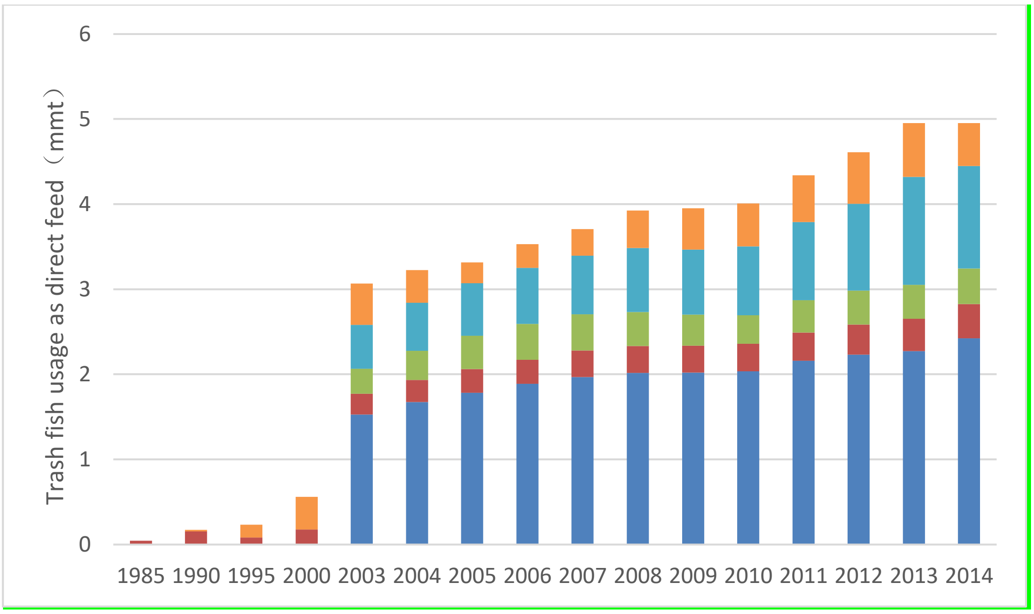


Fig. 26 Trash fish usage as direct feed indicated by coloured bars: dark blue = marine fish, dark red = marine crustaceans, green = marine shell fish, light blue = fresh water fishes, orange = fresh water crustaceans (Report on the Usage of Marine Fisheries Resources by Aquaculture).

A recent study by Greenpeace-China, the most recent and one of the most detailed studies to examine the trash fish component in the country, determined that about 35% (4.6 mmt) of China's marine catch is sold at low prices as feed fish. Production of feed component of China's marine catch ranks sixth among world leading marine fishing countries (Fig. 27). A high proportion (29.4%) of this catch is comprised of commercially important fish, mostly (79.7%) in their juvenile size range. Some are species that are involved in national restocking programs and hence their capture undermines these programmes (Greenpeace-China 2017; Zhang et al., submitted) (Fig. 27).

Regarding direct feeding of trash fish, in 2014 it was estimated from field sampling and available reports that around 35% of the catch in China's exclusive economic zone (4.6 million metric tons, mmt) or half of trawler catch (3 mmt) consists of 'feed fish'. Most of the feed fish were used either in the domestic aquaculture sector directly as (wet) feed or indirectly through the fish feed industry after reduction to fishmeal and fish oil (Greenpeace China 2017; Zhang et al. submitted). Sixty-six% was consumed by marine aquaculture, 34% by freshwater aquaculture, although information and statistics on the volume, species composition, and origins were often incomplete (Greenpeace 2017). These results closely echoed an independent study by Grainger et al. a decade earlier (2005).

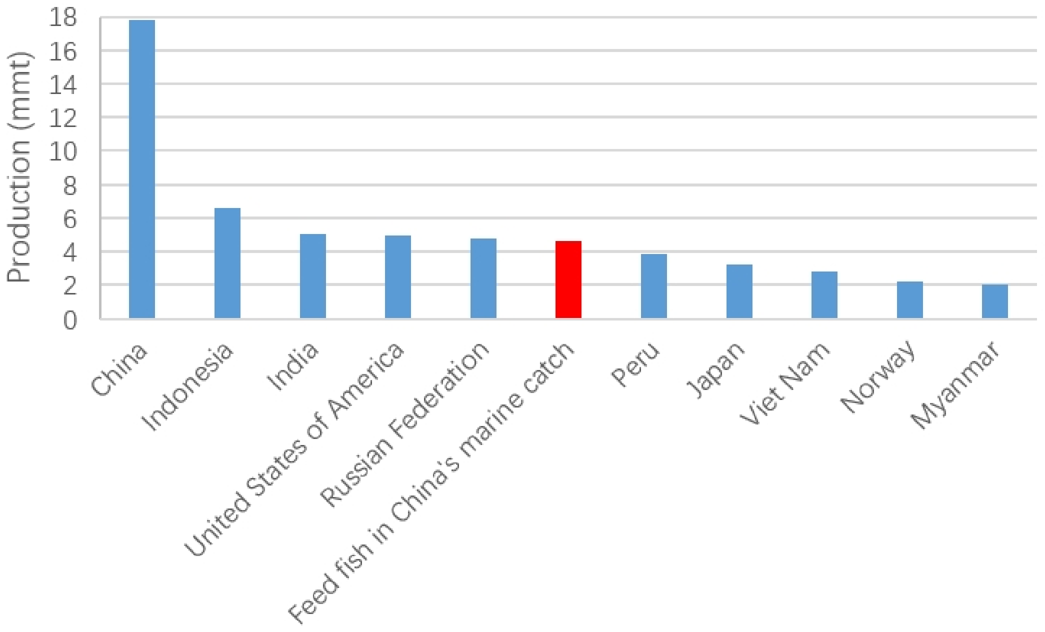


Fig. 27 Production of top 10 world's leading marine (domestic + distant) fisheries countries and feed component of China's marine catch in 2016. (FAO 2018; Greenpeace 2017)

Specifically, the Greenpeace-China (2017) found from the 80 field samples they took from trawler landings from August to December 2016 that trash fish account for about 49% of all trawler catch (trawling accounts for nearly half of China's marine catch);

- edible commercial species accounted for 38.61% of all fish in the 80 samples, 75% of which were in their juvenile size range.
- 218 different species of fish were identified, 96 of which were edible commercial fish. This indicates that current fishing activities of trash fish have broadly impacted the resources of multiple species of edible commercial fish.
- 44 species were found to have existing stock assessments, 40 of which are categorised as over-exploited and 4 of which are categorised as fully exploited or seeing declining numbers. This shows that trash fish are in dire need of a management infrastructure for sustainable exploitation.
- 10 of the species found in samples are used in China's marine stock enhancement project, many of which were juvenile, indicating that the national stock enhancement efforts are being impacted by the fishing of trash fish.

An earlier study had similar outcomes to that of Greenpeace China (2017). Summarizing the situation of low value and trash fish in the Asia-Pacific region, a workshop noted that the utilization of fish for food and non-food is not routinely monitored in China (APFIC 2005). To gain some understanding of ways to handle such monitoring, pilot sample surveys were undertaken at three Chinese fishing ports (Grainger et al., 2005) which showed very large quantities of trash fish (for non-food use) and low value fish (for human consumption) were taken by trawl and sail stow net gears. The proportion of trash fish is highest in trawl catches for December to May when it constituted over 50 percent of the catch. Between 25 percent and 70 percent of low value fish are small-sized species of commercially important fish species with up to 50 percent of trash fish being juveniles of commercially important fish species (APFIC 2005).

The same APFIC (2005) study noted that increased fishing pressure for low value fish and trash fish is worsening overexploitation of commercial fish stocks in the East China Sea, with a consequent negative impact on sustainable development of marine capture fisheries in China. Even if fishing for trash fish and low value fish can be justified on economic grounds, the report noted serious concerns about impacts on the ecosystem and biodiversity and the urgent need for attention to management was highlighted.

Field surveys - Our field surveys were conducted in 3 provinces (i.e. Zhejiang, Fujian and Hainan) along the coast of the East China Sea (ECS) and South China Sea (SCS) during 6 – 19 April 2017. Two locations were chosen in each province and in total 6 locations were selected (Fig. 7). There was more than one landing site in some locations. Sampling of fish was as for Vietnam.

The catches were generally sorted by the vessel crew for different purposes according to the combination of several factors for grading, including species, size and freshness. As just one example, large and fresh hairtail (family Trichiuridae) were sold directly for human consumption, next level of freshness for surimi and then least fresh fish were used for fish feed or fishmeal.

Species of higher commercial value and suitable for direct human consumption were separated first and usually covered with ice on the vessel or shortly after landing. Frozen fish for direct human consumption was also landed from offshore fishing vessels. Some species, for example Japanese anchovy *Engraulis japonicus*, Bombay duck *Harpadon* spp. and lizardfish *Saurida* spp., were separated from other fish for sale, but not used for direct human consumption; the destination of some of this fish is not known but some was sold as raw materials of surimi (although probably not the anchovies). “Trash fish” for fish feed or fishmeal were unsorted, poor quality, sometimes rotting, low priced fishes, crustaceans and cephalopods, placed separately. Juveniles of some relatively valuable species, such as groupers (family Epinephelidae) and snappers (family Lutjanidae), were often observed among the “trash fish” landings. In Baimajing, Hainan, “trash fish” were landed on a different side of the pier from the commercial catches, and in Zhoushan “trash fish” were not permitted to be landed at the wholesale fish market because traders complained about their smell. In general, ‘trash fish” were not covered with ice for preservation.

At least 1kg lots of "trash fish" samples were taken randomly from several buckets of the same vessel for species identification and measurement; note different colour containers indicate different catch categories (Lingshui, Hainan, China, April 2017).

Landings were packed by buckets with vessel number written on. When all fish was landed in the same place, the number of buckets from a vessel was counted by catch type and thus the weights and proportions of each type of catches were estimated (Lingshui, Hainan Province April 2017).

Twenty-eight bags of "trash fish" were collected directly from the landings of fishing vessels in the present study, in which 4 from midwater trawlers, 22 from otter trawlers, 1 from pair trawler and 1 from fish carrying vessel. Only 23 samples had the catches classified by proportion of catch type because it was not always possible to survey or obtain information on the proportion of catches from a particular trawl vessel. In total from 29922.2g of samples collected, the majority (90%) was fish (27889.5g), while 1098.9g and 214.29g were crustacean and cephalopod respectively, and 719.5g could not be identified (Table 22). Since "trash fish" were usually not well preserved, the condition of the specimens was often not good enough for identifying down to species level, in some cases it was not possible to get length measurements, particular for crustaceans and cephalopods so only a subsample could be assessed. In total, 135 (62 families), 3 (3 families) and 46 (16 families) of fish, cephalopods and crustaceans respectively were identified from the "trash fish" samples collected in this study (Table 23). Highest species diversity was found in the samples from Hainan (79), followed by Zhejiang (68) and Fujian (46).

Table 22. Weight in tonnes and abundance in number of fish (F), crustacean (Cr) and cephalopod (Ce) in the trash fish catch samples collected from this study.

	Zhejiang				Fujian				Hainan				Total			
	Biomass	%	n	%	Biomass	%	n	%	Biomass	%	n	%	Biomass	%	n	%
F	9103.63	91.49	643	89.68	7028.39	89.44	1289	89.33	9103.63	94.85	1015	88.80	27736.87	92.70	2947	89.22
Cr	349.24	3.51	69	9.62	520.76	6.63	127	8.80	349.24	3.64	108	9.45	1251.54	4.18	304	9.20
Ce	75.43	0.76	5	0.70	81	1.03	27	1.87	75.43	0.79	20	1.75	214.29	0.72	52	1.57
U	421.71	4.24			227.72	2.90			70.09	0.73			719.52	2.40		
Total	9950.01		717		7857.87		1443		9598.39		1143		29922.22		3303	

U = unidentified.

Table 23. Number of species and families identified in the catch sample from this study.

	Zhejiang		Fujian		Hainan		Total	
	Family	Species	Family	Species	Family	Species	Family	Species
Fish	41	69	32	45	46	81	65	139
Crustacean	8	16	8	20	10	25	15	45
Cephalopod	2	2	2	2	3	3	3	3
Total	51	87	42	67	59	109	83	187

Production volumes and estimates of the proportion of the total trawl catch which comprised of "trash fish" was determined from fishermen interviews and catch sample analyses. Since there can be seasonality in the proportion of "trash fish" and since the data collected in this study were limited to a short time period in the first half of the year (i.e. April/May), a more extensive dataset from a similar study by Greenpeace China (2017), conducted during August – December 2016 (i.e. pre and post summer closure), was used to supplement the "trash fish" fishery data in the second half of the year to account for seasonal differences. The different origins of the data (i.e. from these two studies) are indicated in tables and discussions.

Considering the two studies, the average proportion of "trash fish" in the trawl catches ranged from 30.9% to 60.0% across five provinces studied, based on fishermen interviews and catch sampling, with the highest in Guangxi and the lowest in Guangdong (for details see Appendix II). The overall ratio and volume of "trash fish' in the trawl production along the coastal provinces of ECS and SCS was estimated at 45.4% and 1,924,393 tonnes respectively. Note however, that, these proportions may have been influenced by the practice, in some areas, of trash and commercial food fish being landed in different areas. We have no correction factors to address this possible confounding factor.

The average proportion of raw material for surimi was recorded separately from commercial fish in this study but not in that of Greenpeace's, and ranged from 0% to 22.6% in three provinces (i.e. Zhejiang, Fujian and Hainan; this study). Hence, based on this percentage information the annual production volume of surimi from these three provinces was tentatively estimated at 206,203 tonnes. It is not possible to estimate the overall ratio for surimi for ECS and SCS as there are no data available from Guangdong and Guangxi.

Fish: The top five species/groups of fish in trash fish samples predominantly taken by bottom trawlers by biomass were *Setipinna* sp., *Engraulis japonicus*, *Rastrelliger* sp., *Acropoma hanedai* and *Lophius litulon* in descending order, contributing more than one-fourth of the fish samples analyzed by weight (i.e. 26.44%) (Appendix II), and the top five species/group of fish by abundance were *Acropoma hanedai*, *Bregmaceros* sp., *Rastrelliger* sp., *Setipinna* sp. and *Trachurus japonicus* in descending order, also contributing more than one-fourth of the fish samples analyzed by abundance (i.e. 28.88%).

Most of the species identified have not been assessed according to IUCN Red List criteria and categories. Twenty-five species were Least concern (LC) and 4 were Data deficient (DD). The only threatened species found was *Evynnis cardinalis*, which is listed as Endangered (EN). The majority of the species were not assessed in China Red List, but 20 are listed as Least Concern, 16 are Vulnerable, five are Endangered and one is Data Deficient (Appendix II; Wang & Xie, 2004).

In total, 1739 out of 2947 individuals (59.0% by abundance in number) collected were identified to species level and measured. According to size measurements, they were classified as either being within the likely adult or juvenile size ranges. The proportion of juvenile fish was about 44% by abundance for the fish samples which can be identified to species level, and with the body length successfully measured (Table 24). Samples from Fujian had highest proportion of juveniles among three provinces surveyed, while those from Zhejiang had the lowest.

Table 24. The abundance in number and proportion of fish in juvenile and adult size ranges in the samples collected from this study. Only individuals identified to species level and with the body length successfully measured were included.

	Zhejiang		Fujian		Hainan		Total	
	n	% by n	n	%	n	%	n	%
Juvenile	115	23.52	370	60.56	280	43.82	765	43.99
Adult	374	76.48	241	39.44	359	56.18	974	56.01
Total	489		611		639		1739	

Crustaceans: The top five species/group of crustacean by biomass were *Carcinoplax longimanus*, *Leptochela aculeocaudata*, *Oratosquillina interrupta*, *Charybdis bimaculata* and *Portunus argentatus* in descending order, contributing more than one-fourth of the crustaceans samples analyzed by weight (i.e. 47.41%) (Appendix II). None of the species are listed on IUCN Red List.

Cephalopods: There were only 3 groups of cephalopods recorded from the samples, namely Sepiolidae sp., *Loligo* sp. and *Sepia* sp. in descending order of biomass (Appendix II).

4.3 Surimi, fish balls and similar products

The production of surimi is a valuable value-added seafood industry in the region that has grown substantially since its beginnings in the early 1980s. The development of methods for manufacturing surimi from tropical fish species opened up a new avenue of value-adding for many fish species that had previously been sent to the fish meal plants. The development of the surimi industry has enabled a higher prices per kilo for some species groups and also sent fish processing wastes back to the fish meal plants.

The industry for tropical surimi began production in Thailand in 1983 (Pangsorn, 2009) and Thailand accounted for most of the growth in regional production until 2006 (available dataset). According to SEAFDEC (2009) there were 57 plants operating in South East Asia as of 2006, with 41 indicated by Pangsorn (2009) (Fig. 28). The main export markets listed were Japan, Korea, Taiwan and Singapore. Japan consumes over 350,000 tonnes of surimi per year which is sourced from all over the world but China is the biggest consumer (Park 2016).

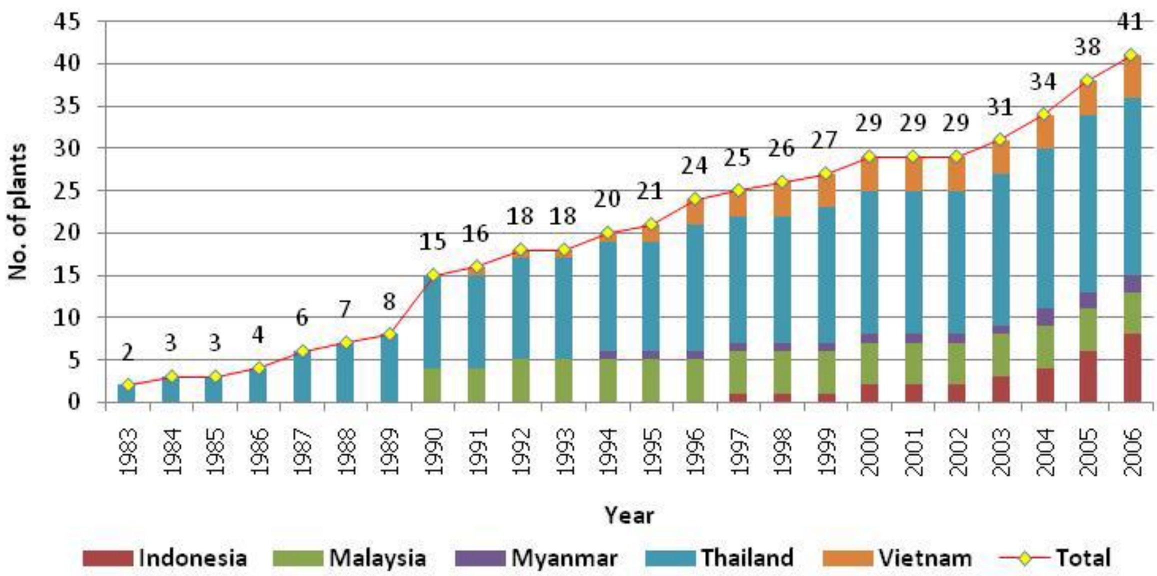
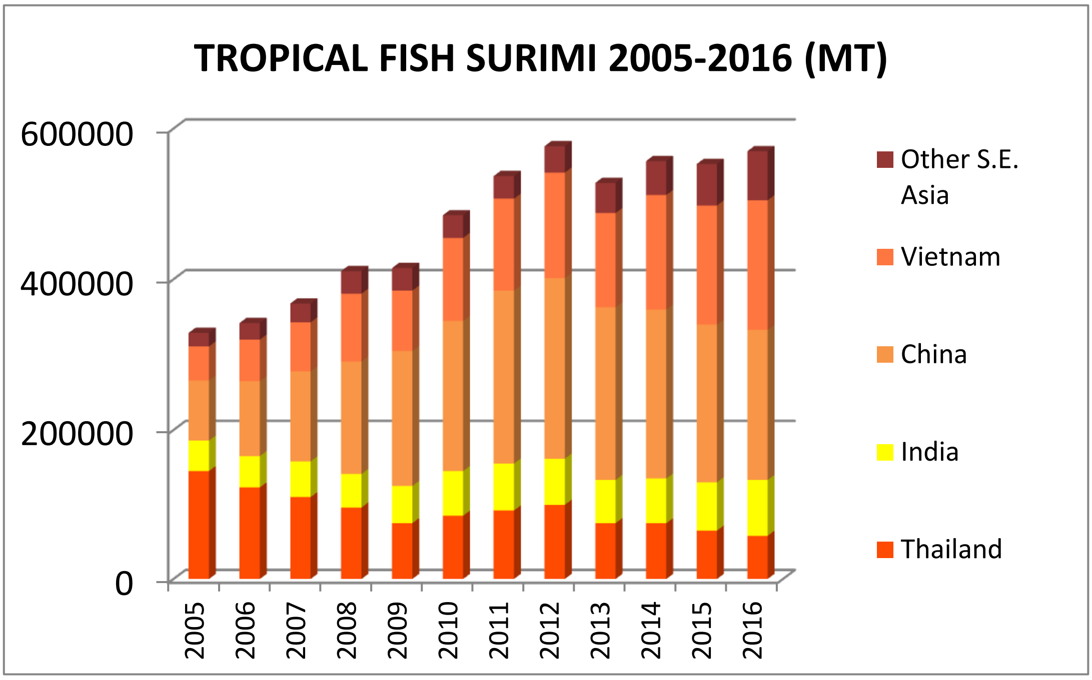


Fig. 28 Growth in the number of surimi plants since 1983 in selected SE Asian countries (Pangsorn 2009)

Thailand's production was 150,000 tonnes in 2005 and this accounted for 43% of regional production followed by Malaysia (100,000t), Vietnam (84,000 tonnes), Indonesia (8,000 tonnes) (and Myanmar 5,000 tonnes). Production in China has grown enormously. During the period 2005 – 2016 the production of surimi grew from 19,704 tonnes to 674,385 tonnes (Fig. 29). This equates to a raw fish weight of over 4.2 million tonnes (conversion factor of 3.5), not all of which would be trawl-caught and not all of which is sourced from tropical species; however further breakdown is not possible and much of it is likely to be taken by trawlers.

Tropical surimi production has been stable with volumes at about 570,000 tons during the period 2014-2016 and this includes the use of silver carp for surimi production in China (approximately 50,000 tons). Surimi production in Thailand and China has been decreasing to 58,000 tons and 150,000 tons, respectively, due to stricter fishing regulations such as controls over IUU fishing (Park 2016).



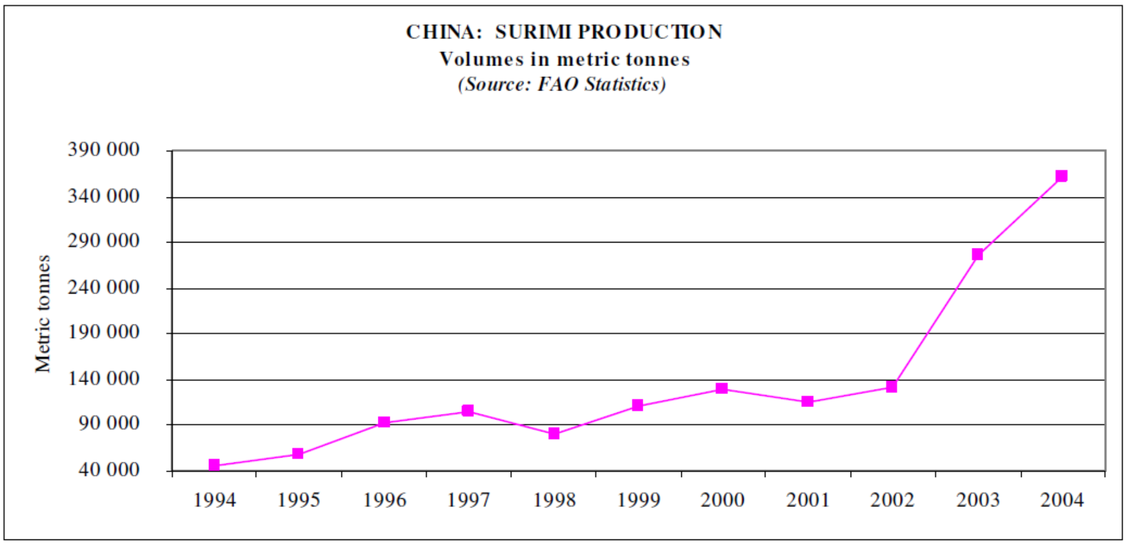
The main products of the surimi sector in general are crab sticks, kamaboko, chikuwa, fish cakes and fish balls, and dried fish snacks (SEAFDEC 2009).

Fig. 29. Source: Pascal Guenneugues (The 10th Surimi School Europe, Madrid, Spain 20-22 September 2017)

Huge variability in production statistics a challenge for understanding trends

Understanding the usage of landed fish provides an insight into how and where the economic benefits are distributed which in turn generates an understanding of the political pressures and willingness to implement reforms. Value added industries help provide employment which, if located in rural areas, is vitally important in terms of improving the opportunities and incomes of rural people. Understanding the scale of value-added production can be extremely difficult, as illustrated by the production of surimi in China. The issues are not unique to China (nor unique to Asia)

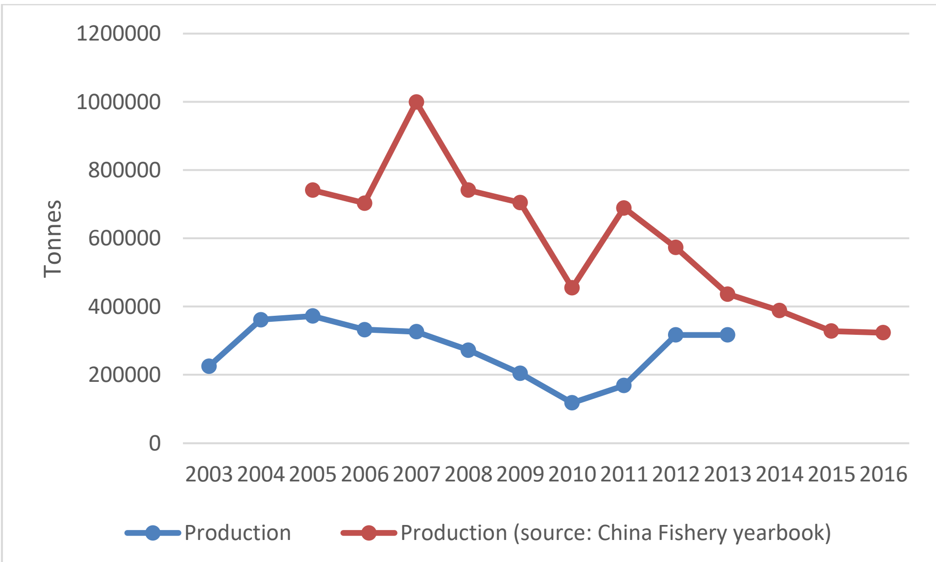
Production in China has grown enormously; during the period 2005 – 2016 the production of surimi grew from 19,704 tonnes to 674 385 tonnes according to the China Yearbook but these data are very different to the FAO data (see graph below) and the different data sources likely cover different ranges of ssepcies. This equates to a raw fish weight of over 4.2 million tonnes (conversion factor of 3.5), not all of which would be trawl-caught and not all of which is sourced from tropical species.



Surimi production in China (1994-2004) (Vidal-Giraud and Chateau 2007-FAO statistics)

According to Li et al (2009) surimi production in China was based on manual labour prior to the introduction of automated processing machines from Japan in the mid 1980's.

According to Zhao and Shen (2016) the production of surimi (and dry cured) products has grown slightly from 2010 to 2015



Different estimates of annual fish fishmeal production according to two sources: FAO in blue and China Fishery Yearbook data source (five provinces) in red.

4.4 Catches of key species and surimi grades made from particular species

Whilst any species of fish can be made into surimi, in tropical waters, the main species are species mostly taken by trawl fisheries (some by purse seine) -

- threadfin breams (*Nemipterus* spp.),
- big-eye snappers (*Priacanthus* spp.),
- croakers (*Pennahia* and *Johnius* spp.),
- lizardfishes (*Saurida* spp.),
- goat fishes/red mullets (*Upeneus* spp. and *Parupeneus* spp.),
- sea breams (*Evynnis* spp.) and
- hairtails, also called ribbon fish (*Trichiurus* spp.).

These species are also commonly used in southern sub-tropical Japan and are known as itoyori, kintokidai, guchi, eso, himeji, renkodai and tachuio, respectively (Tan et al., 1994).

Threadfin bream is the species utilized for surimi production in the largest quantity in SE Asia and India. Itoyori surimi is well accepted in Japan, particularly in the southern part, and is the raw material of preference in Southeast Asia because of its white colour, smooth texture, strong gel-forming ability, and easy processing. This has resulted in increased production of surimi from threadfin bream in all countries where itoyori are available (Guenneugues and Ianelli, 2014). Species recorded in the literature (primarily SEAFDEC 2009, Pangsorn et al 2007) or from company sources (*) include:

- Forktail threadfin – Nemipterus furcosus *
- Ornate threadfin – Nemipterus hexodon *
- Japanese threadin – Nemipterus japonicus *
- Mauvelip threadfin – Nemipterus mesoprion
- Doublewhip threadfin – Nemipteris nematophorus *
- Nemipterus tolu *
- Nemipterus virgatus * (note, not mentioned as used in Thailand but occurs there)
- Redspine threadfin – Nemipterus nemurus
- Notched fin threadfin – Nemipterus peronei
- Fivelined threadfin – Nemipterus tambuloides
- Delagoa threadfin – Nemipterus bipunctatus
- Lattice monocle bream – Scolopsis taenioptera
- Rosy dwarf monocle bream – Parascolopsis eriomma
- Dawn threadfin – Nemipterus aurora * (also used for fish meal)

In Southern Japan, **lizardfishes** (*Synodontidae*), which is eso in Japanese, has long been considered a high-grade raw material for surimi with high meat yield, white colour, unique flavour, and firm gel-forming ability (Itoh et al., 1995). However, the freshness and gel-forming ability decreases quickly over time, even in ice, therefore only fresh raw material is used in Japan.

Lizardfish is considered a low value fish. This species often ends up with low grade surimi due to its high level of protease enzymes that make gel texture soft. It gives a white surimi with low gel.

Lizardfish (*Saurida waniese*) is commonly used in Thailand for dried fish snacks and is used in combination with itoyori for the production of crabsticks, fish balls and other surimi products. Lizardfish surimi also became an alternative to jack mackerel surimi in Europe to mix with Alaska pollock for crabstick production and is used for fish cakes in Japan and Korea. The main species of lizardfish in these countries are *S. tumbil* and *S. undosquamis* (the usual size is 10 to 20 cm) (Guenneugues and Ianelli, 2014). Species recorded in the literature (primarily SEAFDEC 2009, Pangsorn et al 2007) or from company sources (*) include:

- Slender lizardfish – Saurida elongate *
- Shortjaw lizardfish – Saurida isarankurai
- Greater lizardfish – Saurida tumbil
- Brushtooth lizardfish – Saurida undosquamis
- Variegated lizardfish – Synodus varigatus
- Synodus fuscus
- Gunthers lizardfish - Synodus kaianus

Big eye snappers (kintokidai in Japanese) belong to the family *Priacanthidae*. Two species are represented in the South China Sea area: *Priacanthus tayenus*, which is more abundant, and *P. maracanthus*. Both species have a bright crimson colour with a thick, tough skin. Unlike threadfin bream, which often have burst-belly when kept in ice for too long, bigeye snapper has a longer shelf-life in ice (Guenneugues and Ianelli, 2014).

Two different types of kintokidai are found in Southeast Asia: the first one of large size and red colour (100 to 200 g) gives white meat with high gel while the second one of small size (30 to 70 g) and usually greyish color gives darker meat with low gel. Big eye snapper is abundant in trawl catch and often landed in substantial quantities. Due to its appearance and thick skin, it is not consumed directly and is therefore a suitable raw material for surimi manufacture. It can reach a size of 30 cm; however, the average commercial harvest for surimi is 10 to 15 cm (Guenneugues and Ianelli, 2014). Species recorded in the literature (primarily SEAFDEC 2009, Pangsorn et al 2007) or from company sources (*) include:

- Red bigeye – Priacanthus macracanthus
- Purple spotted bigeye– Priacanthus tayenus *

Croakers (*Sciaenidae*) includes two main species, each having different characteristics. Small yellow croaker (*Larimichthyspolyactis*) (kiguchi in Japanese) gives a white high gel surimi that has long been a preferred species for the traditional kamaboko industry in Japan, especially in the Odawara area and Southern Japan. Kamaboko made from croaker or 'kiguchi' surimi has a distinctive taste and texture, distinguishing it from the relatively blander taste of kamaboko made from Alaska pollock. Surimi production from kiguchi in India has been limited in recent years due to the high price of fish raw material. Croaker (shiroguchi in Japanese) gives a low grade surimi (low gel, darker color). It is processed as a single species in India and is used in mixed fish surimi in Vietnam and China. Species recorded in the literature (primarily SEAFDEC 2009, Pangsorn et al 2007) or from company sources (*) include:

- *Johnius* spp
- *Pennahia argentata **

- *Nibea soldado* *

Goatfish (*Upeneus spp.*) and **red mullet** (*Parupeneus spp.*) are landed in Thailand, India, Vietnam, and Indonesia. The bigger sized fish (100 - 200g) are sold whole round or processed into skin-on fillets for Europe and other markets. The smaller sized fish are processed into surimi called himeji in Japanese. It is slightly pinkish in color due to its skin color and usually has low gel strength. Species recorded in the literature (primarily SEAFDEC 2009, Pangsorn et al 2007) or from company sources (*) include:

- Cinnabar goatfish - *Parupeneus heptacanthus*
- Bensasi goatfish - *Upeneus japonicas*
- Dark barred goatfish – *Upeneus luzonius*
- Sulphus goatfish – *Upeneus sulphureus*
- Ochre banded goatfish– *Upeneus sundaicus*
- *Upeneus parvus* *

Hairtail or **ribbon fish** (*Trichiurus lepturus*) has an elongated and compressed body, is steel-blue in colour with a metallic sheen, and is silvery-grey when dead. It is common in the Indo-Pacific region, up to Japan in the north and southward to Queensland, Australia. It is commonly caught in coastal waters and trawling grounds, feeds on crustaceans, and fish and has a typical size of 70 - 90 cm, with a maximum of 110 cm. Ribbon fish surimi has composed a large portion of the Chinese surimi production. Large-sized fish caught all over Southeast Asia are exported to China for the table fish market while smaller sizes go to surimi production. Although it has a low gel-forming ability and the surimi is generally dark in colour, it is used popularly in Korea and Japan for fried surimi seafood because of its good flavour and cheaper price.

Sea Bream is another species caught in large volumes in the South China Sea and landed both in the Northern part of Vietnam and Southern part of China. The two main species are Yellowback seabream (*Evynnis tumifrons*) (renkodai in Japanese), mostly caught in China, and threadfin porgy or cardinal porgy (*Evynnis cardinalis*) (hirekodai in Japanese), landed in both Vietnam and China. Seabream gives high quality surimi with high gel and white colour, like threadfin bream surimi. One problem reported both in Vietnam and China with this species is a chemical (chlorine-like) smell that sometimes develops in the fish meat due to the fish feeding on seaweed that gives it a strong smell at certain times of the year in some fishing grounds.

Several DNA studies show a wider variety of species than listed above as just about any fish (or shellfish, in the case of squids) can be used to make surimi, including the Philippine damsel (*Pomacentrus philippinus* (Pepe et al 2007), and IUCN listed vulnerable shovelnose ray (*Rhinobatos jimbaranensis*) (Galal-Khalaf et al 2016) and an IUCN cichlid (*Paretroplus maculatus)(*Giusti et al 2017*)*. Some individual samples tested by DNA studies had up to 15 different species (Giusti et al 2017), where DNA identifications beyond family/genus were possible. The mixing of finfish and molluscs is not just a potential sustainability issue but a food safety issue for those with allergies.

Species volumes

Across the region (SEAFDEC 2017) for 2014 the contribution of each group to the production of surimi is shown in Figure 30.

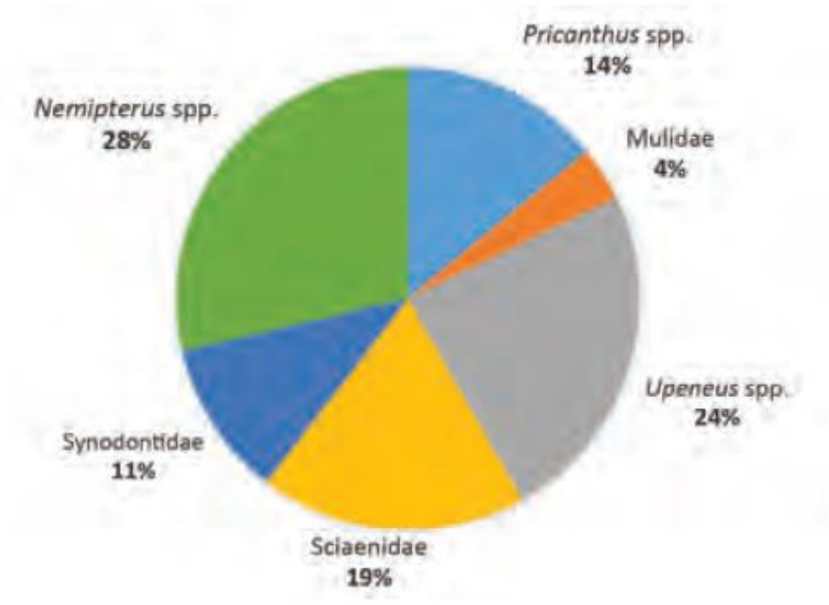


Fig.30 Production volumes by taxon for surimi (SEAFDEC 2017)

There are variations in the dominant species used for surimi in each country within the region as set out in Table 25.

*Table 25 – Volumes of whole fish used for the manufacture of surimi (sources as below) (Funge-Smith et al 2012 using data from 2005 [black figures]) *South China Sea provinces only. Figures in Red are derived from Fisheries Statistics of Thailand 2007, Information Technology Centre, Department of Fisheries, Ministry of Agriculture and Cooperatives, Report 5, 2009. Figures in blue (Indonesi) from Pangsorn (2009).*

Country	Threadfins tonnes	Lizardfishes tonnes	Goatfishes tonnes	Croakers tonnes	Big eye snappers tonnes	Barracudas tonnes	Others tonnes
Thailand (2007)	189000 92500	190000 42700	119000 ND	Included with goatfish 43800	105200	11700	32000
China *	Nd	Nd	Nd	Nd	Nd	Nd	nd
Malaysia	127300	154100	67000	Included in snapper	100500	214400	6700
Vietnam		67620		55860	126420		44100
Indonesia	21760 62000	27000	4160 35000	3200 60000	18000	2560	320

There is a considerable amount of uncertainty in the figures provided by Funge-Smith et al (2012) as is evident above. For example, the figures for Thailand differ substantially from the Thai yearbook data (532,000 t versus 295,900 t of raw material used). Goatfishes do not appear in the Thai Yearbooks (Anon 2014) but they appear in the Funge-Smith et al (2012) data. Conversely, bigeye snappers appear in the Yearbook information but not in the Funge-Smith et al (2012) data. There is a significant difference too between the 2005 figures for Indonesia (total 32,000 t) (Funge-Smith et al 2012) versus the 2005 production data (202,000 t) set out in Pangsorn (2009). The reasons for these differences are potentially many but could include:

- Some species may not be used for surimi in that year (but this seems unlikely);
- Some species may be used for products other than surimi and thus reported landings may be higher than the surimi production figures indicate (likely). Some species will be used locally either fresh or processed (e.g. dried, salted etc) and some species (e.g. some threadfins) will be filleted, frozen and exported;
- There may be significant trade in species. For example, quite large quantities of fish are/were exported whole from Indonesia;
- Landings data may be incorrect or not reflective of catches in country EEZs. For example, for many years fish caught by Thai vessels in the waters of other countries were recorded as being caught in Thailand if landed at a Thai port;
- IUU fishing.

Changes to access policies, often designed to encourage the construction of processing facilities in catching countries, has shifted the production balance because governments are keen to capcture the benefits of value added processing in the country of capture. Exporting whole fish and processing it in another country simply exports much needed employment. Indonesia, for example, has encouraged more and more joint ventures (Indonesian and other country companies) between fishing companies and this has helped create local employment opportunities. However, other policy changes, such as the trawl ban, will negatively affect employment as the raw material available for processing will decline, if not dry up. The growth in the number of surimi plants in Indonesia (from 8 processing plants in 2005 to 21 in 2015) will undoubtedly have been affected by the recent trawl ban. Overfishing will also be a factor as resources becomes depleted on either or both an area or species basis. Indications of volumes used in the SEAFDEC region and of species in a major surimi producer, Thailand, are provided in Figs.31 and 32.

4.4.1 Surimi use

Surimi is in demand both in and outside of the region and there is a significant international trade with most of the demand coming from China, Japan and Korea. Figure 33 sets out the consumption figures for surimi across the region (Park 2016).

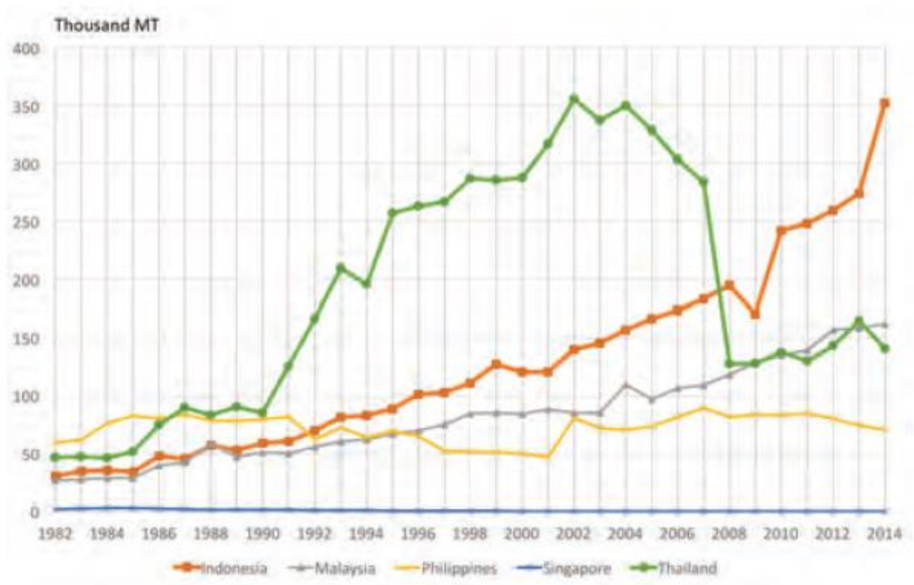


Figure 31 Production volumes of species used for surimi (SEASOFIA 2017) (note that China is not part of SEAFDEC)

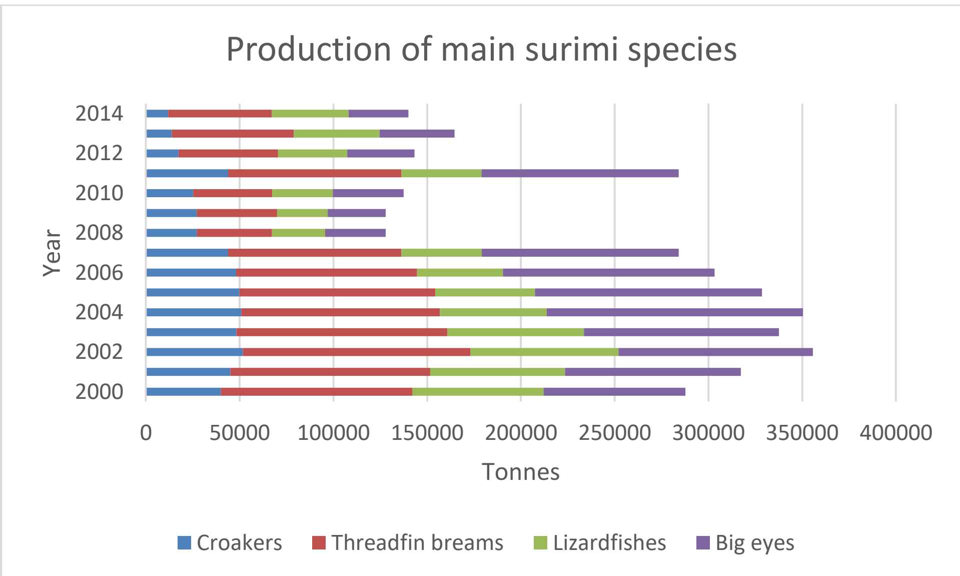


Fig. 32. Main surimi species production in tonnes in Thailand (Thai DoF Yearbooks)

Fig. 33. Consumption figures for surimi in SE Asia (Park 2016)

Asia (including India) uses more than 85% of the global surimi production (820,000 tons in 2016). The top three countries (China, Japan, and S Korea) produce over two million tons of surimi-based seafoods a year. As for the *per capita* consumption of surimi seafood, it is 8.93 kg for Singapore, 6.86 kg for S Korea, 4.71 kg for Japan, 2.70 kg for Hong Kong, 2.12 kg for Taiwan, and 0.87 kg for China. The consumption of fish balls in Hong Kong is enormous at 0.27 kg per person (2000 tons/7.34 million people) (Alfred Fai Hui fish ball maker in Hong Kong pers. comm. to Jae Park).

4.4.2 Percentage of production yield

Even though Japan celebrated 900 years of surimi production in 2015, modern surimi production started in the mid 1980s. Surimi manufacture consists of various steps to isolate fish myofibrillar proteins by heading, gutting, mincing, washing, dewatering, refining, pressing, and freezing with cryoprotectants (Park et al., 2014). As it tries to remove all soluble proteins and fat, the production yield depends on how much water is mixed with mince. Mixing time and temperature also affect the production yield. In the mid 1980s to 1990s, the typical recovery rate was 15%. With the development of machinery (cutting device, decanter, and others) and the efforts made by processors, the current production yield in surimi is 28-36% depending on species or manufacturer. Interviews with surimi plant operators in Vietnam conducted as part of this project found that the conversion rate to surimi and fishmeal from raw materials was between 1:2.6 and 1:3 to 1:4 respectively based on interviews (Appendix I).

Solid wastes from the processing of fish for surimi are collected and processed into fish meal. In field work conducted for this project interviews with the staff from fish processing plants found the preference of the type of raw materials for surimi and fishmeal to be different in terms of target species composition, quality and storage methods. The raw materials for surimi production were generally large fish, comprised of *Nemipterus* spp., *Saurida* spp., *Trachinocephalus* spp. and *Xyrichtys* spp., and relatively fresher and covered with ice. The raw materials for fishmeal production were generally small rotting fishes with no particular dominant species, which were not suitable for direct human consumption or further processing for human food (Appendix I).

4.5 Fish meal, fish feed (direct feeding of whole fish) and other animal feeds

According to Huntingdon and Hasan (2009) fish has been used for a wide variety of purposes other than feeding people, for centuries. The most common usage has been for the feeding of other animals such as fish and invertebrates, pigs, ducks, chickens, foxes and minks. Fish may be processed into fish meal and oil and then incorporated into compound animal feeds, mixed raw/whole with plant materials and fed to farmed fish or fed directly to animals.

The demand for fish meal or fish powder (sun dried before grinding – Edwards et al 2004) has grown as aquaculture production has grown and there has been a gradual shift away from its use in the pig and poultry industries (IFFO 2016) as rising prices have forced producers to either seek alternatives or become much more efficient in their usage of fishmeal and oil, highlighting the shift towards the aquaculture sector. According to IFFO (2016) the global use of fish meal and fish oil is allocated as illustrated in Figs. 34, 35. Fish oil is increasingly in demand as a nutraceutical (IFFO 2016).

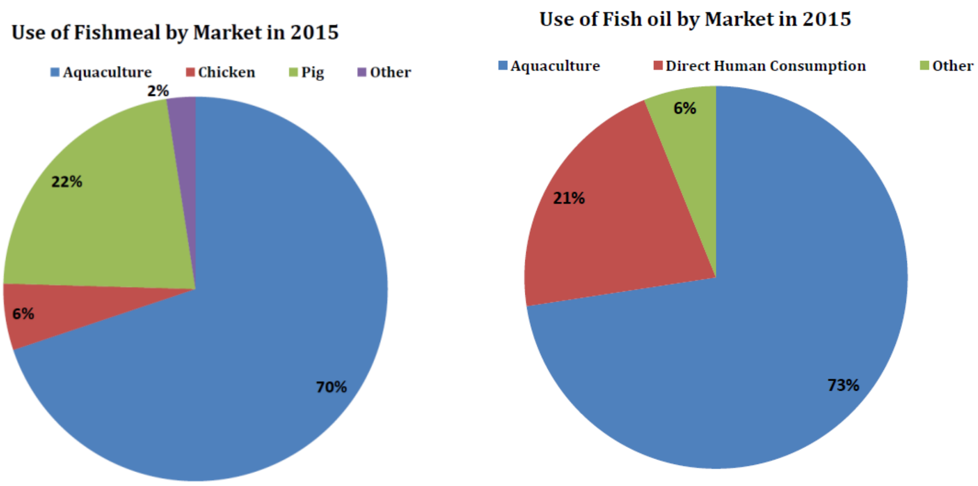


Fig. 34 Global use of fish meals and fish oils (IFFO 2016)

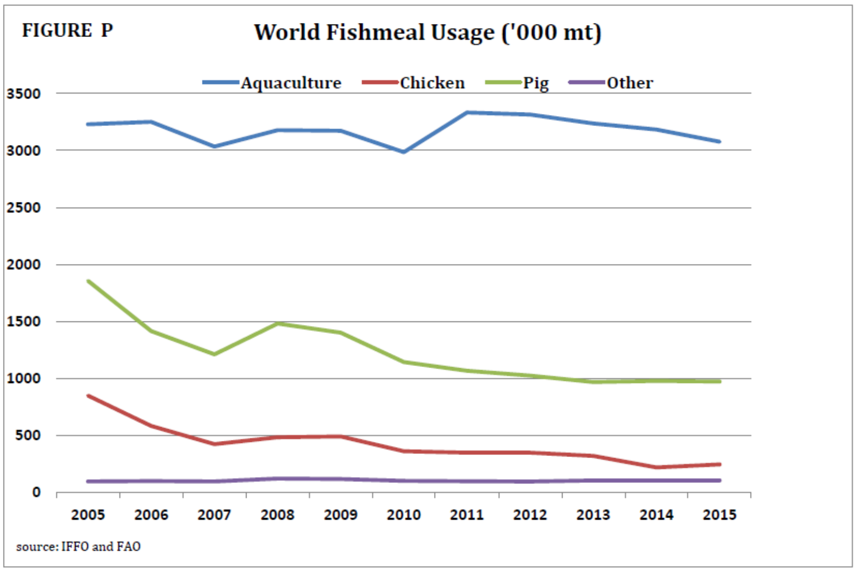


Fig. 35 Global use of fishmeal by sector (IFFO 2016)

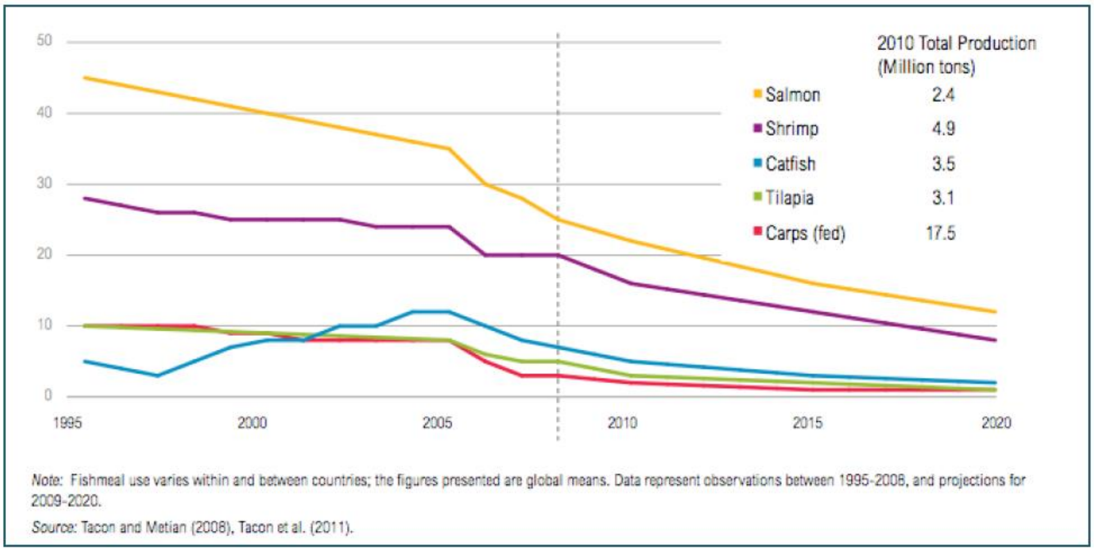


Fig 36 Decline in fishmeal in fish feed diet as a percent, past and projected (FAO 2014).

Part of the reason for the flatline production of fish meal despite the ongoing increase in aquaculture production is the declining inclusion rates of fishmeal in fish diets (Fig 36) and the same is occurring for poultry and pigs (FAO 2014, Auchterlonie 2016). So while fish species become more domesticated the inclusion rates plummet this will be countered by increased need for total feed volumes overall by increased feed use with intensification and growth in aquaculture. For Asia, a major producer of farmed shrimp (and catfish), for example, the demand for fish meal will be affected by both the declining requirements per kilo of farmed product and the overall increase in production.

For small scale fish farmers in Asia there remains a strong demand for whole feed fish, either because of a belief that it performs better than manufactured feed or because it is cheap and locally available (Hasan 2012). Gaining an understanding of the extent of whole feed fish use and the volumes used is very difficult (Table 26).

Table 26. The Asian region is a major producer of fishmeal with four of the top ten world producers being found in Asia (International Fishmeal and Fishoil Organisation Yearbook 2016)

	2011	2012	2013	2014	2015	% change 2015-2014	Average 2014-2011
Peru	1,679.9	841.8	1,115.3	524.6	852.2	62.4%	1,040.4
Thailand	495.0	487.0	450.0	460.0	420.0	-8.7%	473.0
China,PR	530.0	535.0	560.0	450.0	400.0	-11.1%	518.8
Chile	549.5	483.0	320.1	397.7	322.1	-19.0%	437.6
Vietnam	195.0	245.0	275.0	310.0	285.0	-8.1%	256.3
U.S.A	274.5	259.5	235.2	223.6	263.7	17.9%	248.2
Denmark	163.0	89.9	139.7	165.6	206.6	24.8%	139.5
Japan	183.4	186.2	183.1	186.6	184.1	-1.4%	184.8
Norway	107.4	98.4	96.8	144.6	167.1	15.6%	111.8
Iceland	91.2	133.7	121.7	92.1	153.4	66.5%	109.7

As the demand for fishmeal for aquaculture has grown the sources of fish meal have diversified. Trawls are not the only gears utilised and, depending on the country, there may be trash fish produced from gillnets (Funge-Smith et al 2005), purse seines, push nets and stow nets. Meal derived directly from wild harvest resources has been supplemented by meals derived from processing wastes from the booming processing sectors (Huntington and Hasan 2009, SAL Forest 2014 and Anon 2017 for Thailand). The global production of seafood processing wastes and bycatch has been estimated at 25-30 million t (Naylor et al 2009), of which, in 2002, an estimated 5.6 million t were converted into fishmeal and fishoil. According to Funge-Smith et al (2012) it has been estimated that 56% of fish meal produced in the region is from trimmings which is far greater than the global average of 25%. In the case of Thailand, trimmings supply about half of the source material for fish meal production (Anon 2017) (Table 27)

Table 27 Main sources of raw material for fishmeal production in Thailand. Source – Anon 2017

	2011	2012	2013	2014	2015	2016	2017 (Jan–Jun)
Trimming from tuna canning industry	94,750 (19%)	99,410 (20%)	91,958 (19%)	86,365 (18%)	68,644 (18%)	67,600 (21.53%)	32,601 (23.42%)
Fishmeal from other sources	146,757 (29%)	132,083 (27%)	166,256 (33%)	143,121 (30%)	102,966 (27%)	126,037.58 (40.15%)	52,544.75 (37.74%)
Whole fish	261,634 (52%)	261,044 (53%0	233,350 (48%)	248,608 (52%)	209,748 (55%)	120,313.19 (38.32%)	54,083.78 (38.84%)
Total	503,141	492,537	496,564	478,094	381,358	313,950	139,230

Trimmings supply meal from both farmed species such as Pangasius and shrimp (and possibly other species as well) and wild products (Edwards et al 2004). Fish caught in the region are supplemented by fish caught outside but imported for processing. An example is the large volume of tuna fish meals produced in Thailand as a byproduct from the large local canning industry (Anon 2016, Preechajarn, 2015).

Gaining an understanding of the use of trawl-caught fish for animal feeds is extremely difficult due to the diversity of sources, the lack of reporting, complex supply chains and varied use of catches from single fishing trips (from food fish to surimi to fish feed according to species, quality and markets). As just one example, Khemakorn et al (2005) map supply chains for fish meal in Thailand, as they existed at that time (Fig 37).

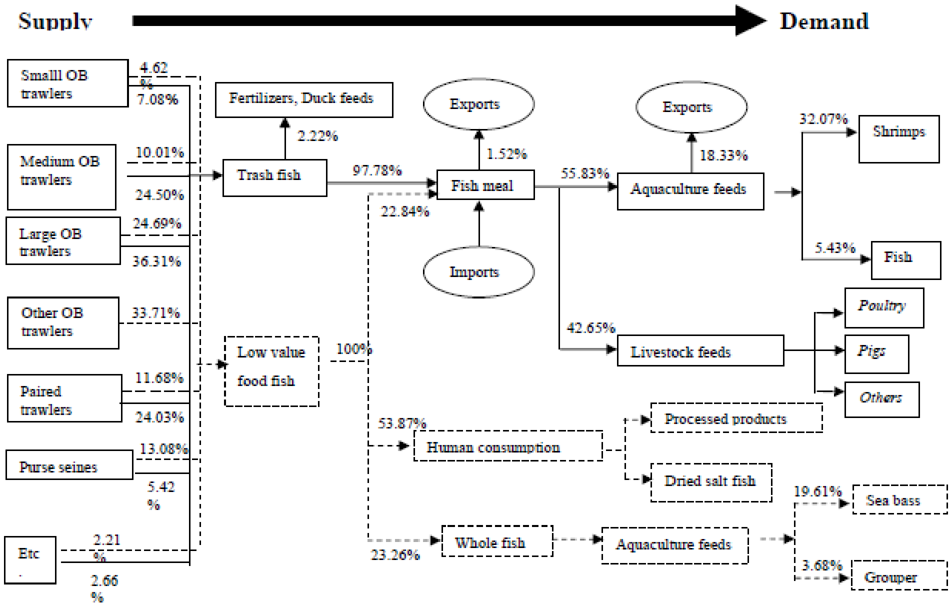


Fig. 37 Market pathways of 'trash fish' and 'low value food fish' in Thailand

4.6 Fish meal production volumes by country

Fish meal pile in processing plant in Vietnam (left). Wood collected for fire used to dry fishmeal (right) 2017

Estimates of the amount of fishmeal produced annually are highly variable due to the different data collection methods used, or absence of data collection in some countries. In Thailand, for example, the government collects data from factories directly. The industry generates estimates based on the production of farmed fish and poultry/pigs modified by conversion factors (SAL Forest 2014). Both of these approaches have their own uncertainties and the diversity of raw material streams (whole fish versus processing wastes) makes the generation of data on the use of trashfish very difficult. In Thailand, the government also monitors trash fish production directly which is different to Vietnam and China, for example, where there is little or no monitoring or publicly available data (see country reports in Appendices). Table 26 illustrates the diversity of estimates of fishmeal that can be found for Thailand, as just one example, showing considerable variation in estimates of production. See also the Box above on variation in fishmeal estimates in China from China government statistics and FAO.

4.6.1 Thailand

Thailand has the most comprehensive dataset on fish meal production and it documents growth in production since the 1960s when six plants were established to make use of the large volumes of trawl bycatch generated by the establishment and rapid growth of trawling in the Gulf of Thailand. Estimates come from a number of sources (Table 28). The data in Fig. 38 are from www.indexmundi.com which takes data from the US Department of Agriculture and, being cognisant of the points made above, indicates the rapid growth in production in the late 1960's reaching a plateau in the mid 1980s.

Table 28 Estimates of fish meal production in tonnes. . DoF (2006) Statistics of fisheries factories 2004. Technical paper No. 7/2006. Information Technology Center, Department of Fisheries. 36 pp. quoted in Lymer et al (2008). # Thai Dept of Fisheries – Fishery Statistics Analysis and research Group (2013) quoted in SAL Forest (20XX) Figure 15.*

Year	FishStat	FAOstat	IndexMundi	ThaiDoF	ThaiDoF	TFPA	IFFO
2000	721815		380000	299073*	325000#		
2001	723198		380000	378352*	310000#		
2002	502000		390000	392583*	310000#		
2003	580588	352230	400000	392312*	350000#		
2004	658359	302700	410000	423866*	325000#		
2005	455500	243290	435000		345000#		
2006	487200	261326	475000		330000#		
2007	442820	256360	480000		330000#		
2008	380360	339180	470000		300000#		
2009	402720	270750	477000		285000#		
2010	520000	373060	477000		280000#		505000
2011	582000	365450	455000		275000#		495000
2012	585000	365450	490000				487000
2013	605000	365450	477000				450000
2014	500000		450000				460000
2015	400000		380000				420000

Fig 38 – Growth in fishmeal production in Thailand (www.indexmundi.com)

The overall level of production conceals some major changes in the source of raw material. Since 2000 there has been a dramatic decline in the proportion of fishmeal derived from trashfish from 52% to 17%. Not only has there been a reduction in the amount of trashfish caught (or categorised as trashfish) and a substantial decline in the trawl catch (which has more than halved) but there is an increasing proportion of fishmeal being sourced from the trimmings of fish processing plants (see Table 29).

Table 29 Fishmeal derived from trashfish # data from Thai Year Books – note that trash fish are also sourced from fisheries other than trawling, such as purse seine, but the volumes are far lower.

Year	Production – fish meal – t (index Mundi)	Trash fish production – t	Fishmeal from trashfish*	% from trash-fish	Total trawl production tonnes #	Trashfish percentage #
2000	380000	775079	200000	52	1620642	27.9
2001	380000	738538	185000	49	1645473	28.0
2002	390000	696 641	174000	45	1681359	26.4
2003	400000	697145	174000	43	1678915	26.3
2004	410000	771723	193000	47	1666492	26.3
2005	435000	601915	150000	34	1607383	28.8
2006	475000	672686	168000	35	1420439	27.1
2007	480000	583276	146000	30	1243654	28.1
2008	470000	442648	111000	24	784991	26.9
2009	477000	468807	117000	24	808696	28.2
2010	477000	418990	105000	22	811526	26.2
2011	455000	355813	89000	20	773317	22.1
2012	490000	321732	80000	16	730750	21.4
2013	477000	323632	81000	17	767323	20.0
2014	450000	301942	75000	17	696543	20.3

Domestic consumption of fishmeal in Thailand has been affected in recent years by a mixture of the impacts of disease outbreaks in farmed shrimp (e.g. Early Mortality Syndrome – EMS) (Preechajarn, 2015) and improvements in the quality of the fish meal (Anon 2016) which has opened up new export markets. Production of fishmeal is expected to decline even further with changes in the availability of raw material due to a clamp down by industry and government on IUU fishing in the region.

4.6.2 Vietnam

Production figures for Vietnam are not well documented. Index Mundi provides the figures below but the data sources are not known (Fig. 39). The Vietnamese Association of Seafood Exporters and processors (VASEP) does not collect information on the production and trade in fish meal. According to Edwards et al (2004) an estimated 933,000 t of trashfish were produced in Vietnam in 2001, the vast proportion of it in the southwest and southeast of the country. Of this an estimated 176,000 to 323,000 t were used in the aquaculture industry. This would produce about 44,000 t to 81,000 t of fish meal if all were converted into fishmeal but they also claimed that 90% of fishmeal used is imported, suggesting that considerable amounts of trashfish are used for direct feeding of farmed species (especially groupers and spiny lobsters) or the manufacture of fresh feeds on the farms (species such as *Pangasius* and snakeheads). Edwards et al (2004) also state that the country produced about 180,000 t of fishmeal, some of which may well come from the wastes generated from processing farmed *Pangasius* and shrimp, which is generally low in protein. Trashfish not used in aquaculture is used in the livestock and fish sauce production sectors or for human food.

The latter use exemplifies the challenges associated with trying to define 'trash fish' which in Vietnam does not specifically refer to fish for animal feed or spoiled fish but can include an unknown quantity of low value fish used for direct or indirect human food production.

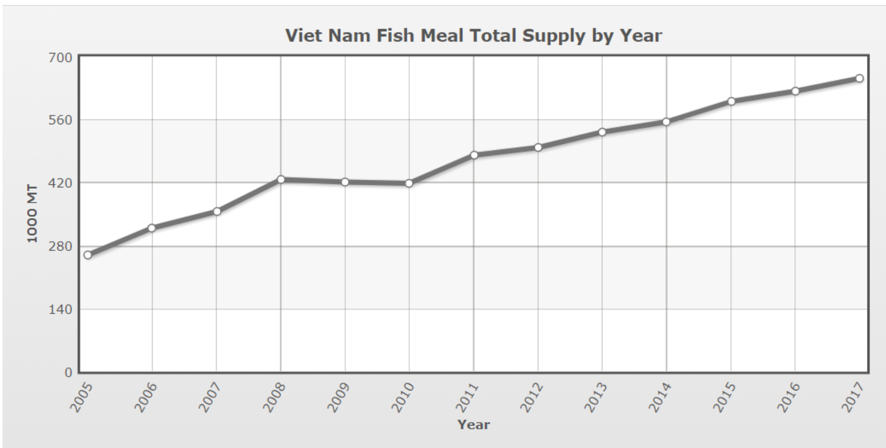


Fig. 39 Fishmeal production in Vietnam (www.indexmundi.com)

No information could be found on the sources of the fishmeal used by IndexMundi.

Vietnam is now a major producer of fish meal (see Table 28) and a key source of fishmeal into China (Table 29). This is in spite of concerns expressed by Edwards et al (2004) that Vietnam had low prospects for the production of quality fishmeal and oil.

Very poor quality fish goes into fishmeal production in both Vietnam (left) and China (right), 2017

4.6.3 China

As is demonstrated for both Thailand and Vietnam there are major variations in the estimates of production from different production sources and China is no exception. Gaining a clear picture of the production of fishmeal and oil in China is difficult although available data clearly indicate a large increase in the 1990s (Fig. 40). Fishmeal is both produced domestically (above) and heavily imported (Table 29). Also see earlier sections and Box (above) for figures. Surimi production is not so high as in other major surimi producers in the regtion.

Figure 40 – Fishmeal production in China (1979-2017) (www.indexmundi.com)

4.6.4 Malaysia

The number of fishmeal plants in Malaysia reported in the national statistics fluctuated between 12 – 23 in MSSCS during 2005 – 2016, while the production of fishmeal fluctuated between 26,756 – 28,882 tonnes over the same period (Fig. 41). The trend of these two subjects however did not mirror. It is suspected that only the large fishmeal plants were reported to the national statistics and thus the the number of plants and fishmeal production volume were likely underestimated. It is also not known if only forage fish or "trash fish" were used as the raw materials for the fishmeal production in these plants.

The trends of the production volume of fishmeal, surimi and the products made from surimi were increasing similarly during 2008 – 2013 in the East coast of Peninsular Malaysia, except for a sharp decrease in 2012 for all kinds of products (Fig. 42). In the national statistics the difference between "surimi" and "products made from surimi", which is reported as fish cake, fish ball and fish crackers, is not clear. Presumably, the former is not processed to as high a food quality grade compared to the latter.

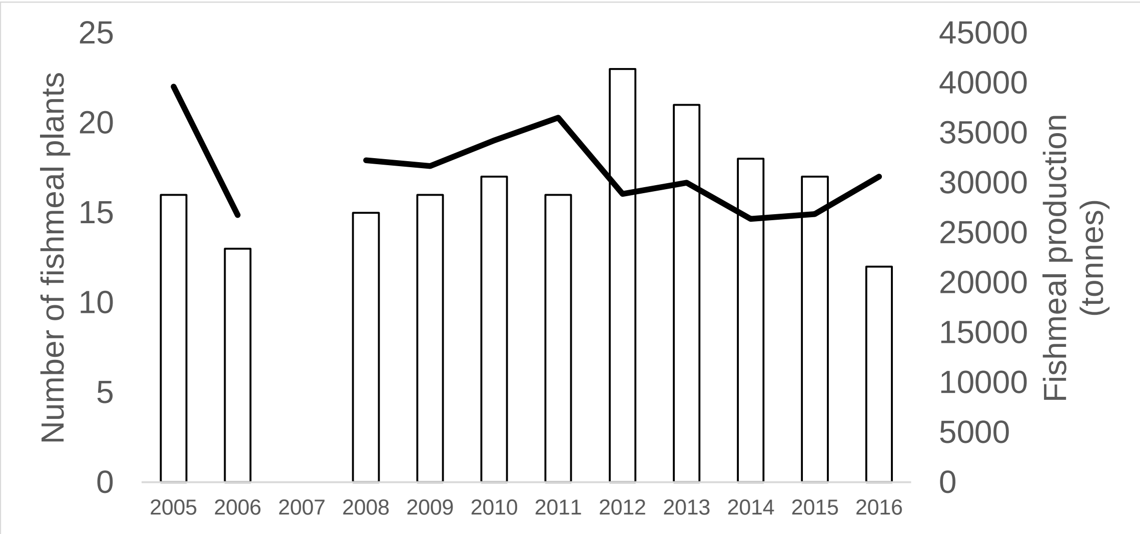


Fig. 41. Number of fishmeal plants (bars) and production of fishmeal (line) in MSSCS during 2005 – 2016. Data not available in 2007 (Department of Fisheries, Malaysia).

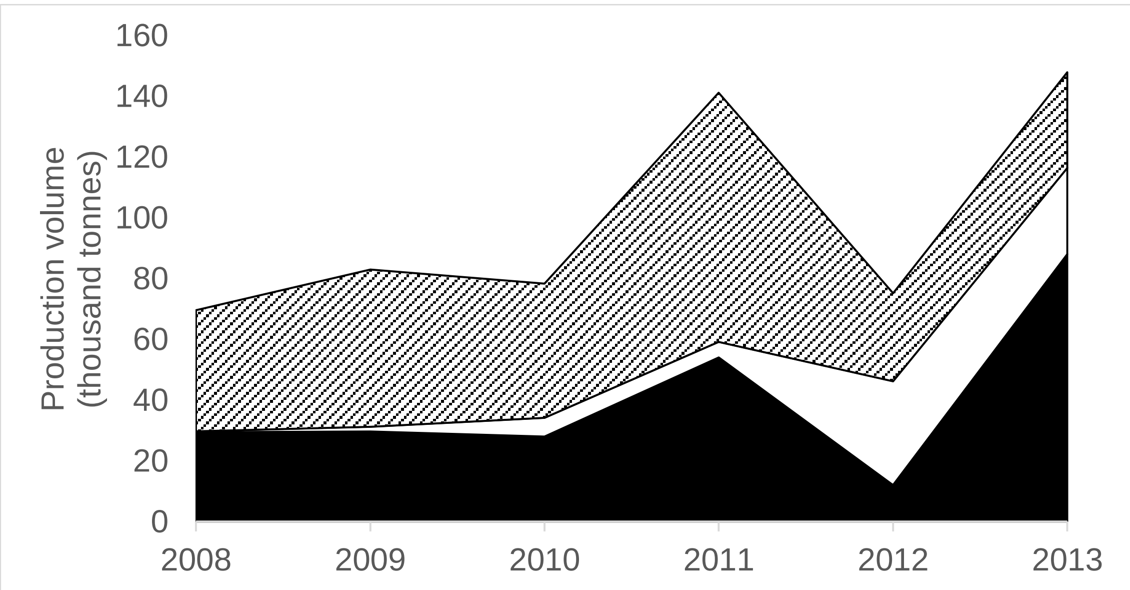


Fig. 42. Production volume of fishmeal (black), surimi (white) and products made from surimi (e.g. fish cake, fish ball and fish crackers on national statistics) (striped) in the East coast of Peninsular Malaysia during 2008 – 2013 (Department of Fisheries, Malaysia)

4.7 International Trade

International trade is an important source of fishmeal even for major producing and user countries, such as China (Table 30).

Table 30. International trade data and production (Funge-Smith et al 2012).

	Country					
	China	Viet Nam	Philippines	Thailand	Malaysia	Indonesia
IFFO (2010) National production	465 600	70 200	0	505 000	46 200	15 000
Fishmeal imported (2009)	1 321 033	124 430	23 780	19 034	21 862	67 785
Fishmeal exported (2009)	56 919	25 731	1 442	62 170	18 263	4 655

China is the world's largest importer of fishmeals and fishoils. The volume imported from Peru is an order of magnitude higher than from any other country (Table 31). Depending on year, the volume reported from the top five countries equivalent to about 3 million t of whole fish (noting that a relatively small proportion comes from trimmings). This is of the same quantum as estimates (Greenpeace China 2017) of the China trashfish supply. According to IFFO (2016) the FOB prices for high quality Peruvian fishmeal in 2014 ranged between USD1.40 and USD1.90 per kilo.

Table 31 Imports of fishmeal to China from the top five countries (Fang, 2017).

2012		2013		2014		2015		2016		2017（Jan-Jul）	
国别 Country	进口量（吨）Import	国别 Country	进口量（吨）Import	国别 Country	进口量（吨）Import	国别 Country	进口量（吨）Import	国别 Country	进口量（吨）Import	国别 Country	进口量（吨）Import
秘鲁 Peru	708,702	秘鲁 Peru	459,600	秘鲁 Peru	510,935	秘鲁 Peru	537,669	秘鲁 Peru	435,668	秘鲁 Peru	555,792
美国 US	172,098	智利 Chile	115,935	美国 US	97,727	美国 US	91,924	越南 Vietnam	127,176	越南 Vietnam	74,854
智利 Chile	125,192	美国 US	108,813	智利 Chile	94,233	越南 Vietnam	74,901	美国 US	91,924	厄瓜多尔 Ecuador	44,833
越南 Vietnam	49,035	越南 Vietnam	66,884	越南 Vietnam	72,461	智利 Chile	65,818	泰国 Thailand	61,329	美国 US	44,437
俄罗斯 Russia	47,762	俄罗斯 Russia	49,159	泰国 Thailand	68,761	泰国 Thailand	61,329	俄罗斯 Russia	58,031	智利 Chile	41,699

4.8 Value of trash fish products

Price data are available for Vietnam and China for various components of trawler catches from the literature and from our field studies, with limited data also sourced from Thailand. Recent pricing from other countries could not be located.

4.8.1 Thailand

In Thailand the price of trash fish varies from port to port and in 2013 (Anon 2014 – Thai Yearbook) the prices ranged between about 4 and 12 THB (USD0.12 to 0.36) per kilo. The price of fish meal varies a lot depending on quality and protein content but ranged from 34 to 41 THB per kilo over the period 2011 to 2017 (Anon 2017). Fish meal factories in Thailand are generally small with production capacities of 3000 to 15 000 tonnes per year (Anon 2017).

Both short and long term market prices have an influence with the growing price for fish meal possibly affecting the sourcing of raw materials (and driving greater efficiency in terms of using fish processing wastes). Fig. 43 shows that fish meal prices have quadrupled over the 30 year period covered which reflects a year on year inflation rate of 5% although it is unclear from the graph whether this growth in prices is inflation adjusted or not. Edwards et al (2004) also reported significant increases (doubling) of prices for trashfish during the period leading up to their survey.

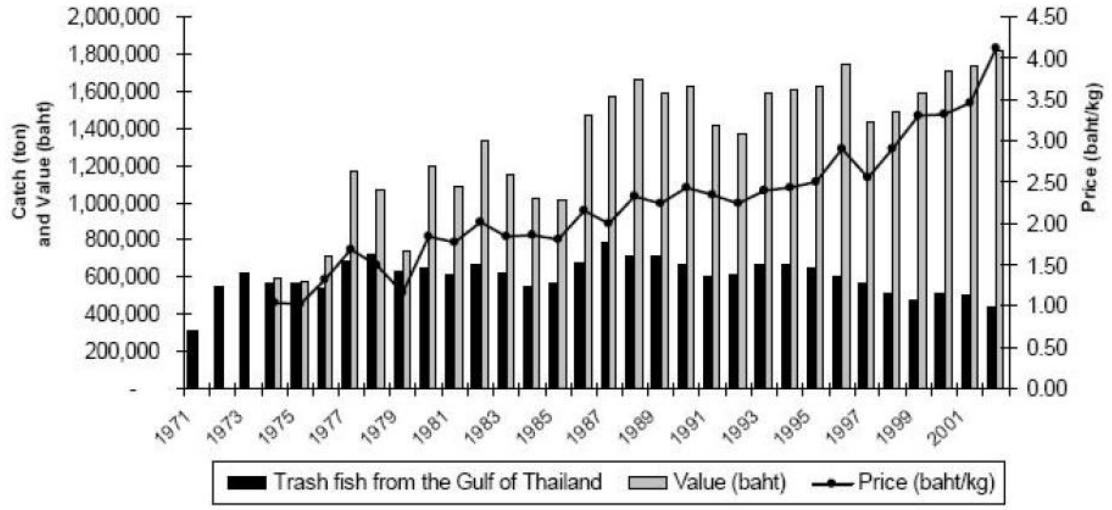


Fig. 43 Catch, value and price of trash fish in Gulf of Thailand (Supongpan and Boonchuwong 2010)

4.8.2 China

In China the selling price of "trash fish" in recent studies from the fishermen varied from CNY0.7 to CNY4.0/kg (April 2017 1US$=6.88 renminbiUSD), and the price almost doubled at each level of the supply chain (Table 32). It should be noted that the selling prices of "trash fish" were collected from trawlers only. The price of "trash fish" depends on various factors, including freshness, gear type of sourcing vessel, type of utilization, season and market (Greenpeace China, 2017). For example, interviewees from processing plants reported that "trash fish" from purse seiners were more expensive than those from trawlers and set netters because of better quality. The price of "trash fish", which could be used for direct animal feed are generally higher than those used for fishmeal production.

The price of "trash fish" was also possibly related to the number of processing plants (i.e. demand) as suggested by interviewees (Appendix II). For example, government concerns about the pollution caused by the fishmeal and surimi production reportedly led to local governments, particularly those in the major fishmeal and surimi production places such as Zhejiang and Shandong provinces in northern China, asking small production plants to combine together with larger ones that have higher environmental and hygienic standards, and some of them have to stop production from time to time. Since "trash fish" decays easily and cannot be stored for a long time unless processing plants have large freezing facilities, the price of "trash fish" in these two provinces was reported to be lower due to poor sales (Greenpeace China, 2017).

Table 32. Price of "trash fish" along the supply chain of fishmeal production in China (Greenpeace China 2017; Appendix II)

	Number of interviewees		Price (CNY/kg) (*CNY/USD=0.14486 on May 5 2017*)		
Province	Processing plants (Our study)	Fishermen (Greenpeace's study)	Selling price of "trash fish" from fishermen (range)	Purchasing price of "trash fish" by the processing plants	Selling price of fishmeal
Zhejiang	6	72	1.6-3.0	1.2-6.0	3.0-12.0
Fujian	0	69	1.0-4.0	-	-
Guangdong	0	73	0.7-1.3	-	-
Guangxi	0	63	0.8-2.0	-	-
Hainan	5	69	1.0-2.8	3.0-4.0	-
Overall	11	346			

4.8.3 Vietnam

Price changes may be due to the increased demand from growing farm production, increased diversion of species into higher value supply chains such as surimi and human food (e.g. use of leatherjackets in Vietnam for human food) (Edwards et al 2004) or changes in market supply. Edwards et al (2004) also documented how one fish sauce factory in Kien Giang province, Vietnam, had stopped using trash fish for fish sauce production due to is rising prices which saw *Pangasius* (catfish) farmers purchasing more of the trashfish.

The selling price of the fishmeal reported from small-scale processing plants was around VND22000 (i.e. USD0.97) per kg while those in the south reported that selling price depended on the content of protein at VND360000 (i.e. USD15.85) per % of protein per tonne (Appendix I). This compares to VND500 per % protein recorded in 2003 (Edwards et al (2004).

In Vietnam, the selling price of "trash fish" from the fishermen varied from VND5000-12000 per kg (i.e. about USD0.22 – 0.53 per kg)[2] (Appendix I). "Trash fish" of larger size and better freshness fetch a higher price. It should be noted that, in this study, selling prices of "trash fish" were only collected from bottom trawlers, and not from any other gear types, such as purse seine. This is noteworthy inasmuch as the price of "trash fish" depends on various factors, including size, freshness, gear type

[2] 1USD ≈ VND22703 (source: http://www.xe.com; accessed on 1 Jun 2017)

of sourcing vessel, type of utilization, season and market, for example larger fish or fresher "trashfish" fetch higher prices; raw materials for surimi production was more expensive than those for fishmeal production. Prices from 2001 (July) are shown for comparison (Table 33).

The selling price of the fishmeal reported from small-scale processing plants in the north and central was around VND22000 (i.e. USD0.97)[1] per kg while those in the south reported that selling price depends on the content of protein in the fishmeal at a price of VND360000 (i.e. USD15.86) [1] per % of protein per tonne (prices were reported by processing plant staff) (Appendix I). Similar findings was also reported in Edwards et al. (2004) whereby the price of fish meal depends on its protein content and sells for VND 150/% of protein. Fishmeal products from the processing plants in Vung Tau in the southern region were mainly sold to larger fishmeal companies such as 'CP Vietnam' for further processing, and thus the selling prices of fishmeal from the small processing plants were controlled by the large companies and also the business environment of the aquaculture sector.

Most "trash fish" processing plants were family-based and small scale in Cat Ba Island in northern Vietnam (Appendix I). The processing plants visited in this location were operated by Chinese. It was reported that fishmeal products were sold to China. However, the supply of raw materials from local vessels was limited, and thus daily operation of the plants was not possible and the volume of products was as low as 50 – 100 tonnes per year. Thus the companies were considering shutting down their plants at the time of our interviews. In contrast, the processing plants in the south were much larger in terms of production volume, ranging from 12000 – 25000 t per year. The one in central Vietnam visited in our study lay in between these two groups at 500 – 600 t per year maximum.

Only one fisherman was willing to talk about the income and expenditure of his operation, reporting the fuel cost to be VND11000 – 12000 litre/day of fishing with employee wages fixed as 40% of revenue, while the revenue could be as high as VND3,000,000,000/year for all kinds of catches. Only one vessel, a stern trawler, specifically reported on surimi: fish for surimi was landed directly at processing plants and sold at VBD10000/kg. This same vessel reported trash fish for fish feed selling at half the surimi price i.e. at VND5000/kg.

Table 33. The selling price of "trash fish" in Vietnam during July 2001. Data are shown in the sequence of the locations from the north to the south [Data source: Dao et al. (2005)]. USD1 ≈ VND14,500.

	Selling price of "trash fish" (VND)		
Location	Min.	Max.	Usage
Hai Phong	800	2,200	Fishmeal, fish feed
Thanh Hoa	700	1,200	Fish powder, fish feed
Da Nang	500	2000	Fishmeal, fish feed, fish sauce
Nha Trang	2,500	3000	Fish feed for lobster
Nha Trang	2,000	3000	Fish sauce
Phan Thiet	500	1000	Fish powder
Phan Thiet	1500	1500	Fish sauce, human consumption
Ho Chi Minh City	700	2000	Fishmeal
Vung Tau	1200	1500	Fishmeal
Vung Tau	1450	1600	Fishmeal

Vung Tau	1500	2000	Fishmeal
Ca Mau	1500	2000	Fishmeal
Ca Mau	1800	2500	Fish feed
Ca Mau	1600	1600	Fishmeal
Ca Mau	1200	1200	Fishmeal
Ca Mau	1000	1200	Fishmeal
Kien Giang	1000	1700	Fishmeal
Kien Giang	1500	1600	Fishmeal
Kien Giang	2500	3000	Fish feed

5 SECTION 5

5.1 Resource management issues in the use of trawl fish catches in Thailand, Vietnam and China

Fish meal in Thailand, Vietnam and China is sourced from:

1. Fish caught in domestic fisheries and used as wholefish – could be targeted or incidental catch
2. Fish caught outside territorial waters and used as wholefish
3. Fish imported as whole fish (wild or farmed) that are processed and the processing wastes are made into fishmeal
4. Locally produced fish (wild or farmed) that are processed and the processing wastes made into fishmeal.
5. Fish that have exceeded their shelf life at local retail outlets (recent innovation – Thai Fish Meal Association pers. comm. November 2017)

This section focuses on wild fish caught in the Exclusive Economic Zones of Vietnam, Thailand and China but noting that fish caught on the high seas or from the waters of other countries may also be used, which can create issues in terms of Illegal, Unregulated or Unreported (IUU) catches, which will be addressed in this section as well.

5.1.1 Ecological context

Thailand, Vietnam and southern China host a very large number of species due to their tropical location and diversity of habitats. In addition, marine productivity is high which is due to:

- large river inputs – contribute large amounts of nutrients to the nearshore zone which fuels the growth of phytoplankton;
- the large area of continental shelf – which creates fishable grounds in the photic zone, i.e. that part of the water column in which sufficient light can penetrate to drive the growth of phytoplankton.

Whilst the waters have been fished for centuries the development of industrial fisheries, especially the trawl fisheries, substantially increased both the area (Watson et al 2006) that could be fished and the catch per person/vessel (Catch Per Unit Effort – CPUE) from the 1960's onwards. Coupled with the absence of controls on how many fishing vessels were to be permitted the rapid increase in fishing effort swiftly overwhelmed the biological capacity of many species to maintain viable populations. This had a series of cascading effects resulting in the creation of conflict between existing, traditional, fisher groups and fishers in adjacent countries because populations of marine resources extend well beyond national boundaries. The early (1960's) depletion of the Gulf of Thailand created a large fleet of vessels that moved into the waters of other countries seeking new fishing opportunities (Butcher 2002 and Butcher 2004) and these added to the growing fleets in the waters of those countries. The declaration of Exclusive Economic Zones under the UN Convention on the Law of Sea (UNCLOS) did little to stem the growth such that by the mid 1980's evidence of depleted fish stocks could be found in Vietnam, Malaysia, Indonesia, Philippines, China and beyond.

The depletions occurred not just on a spatial basis with fleets overfishing one area before moving on to another. Species which were uncommon, matured late or had few young, such as stingrays, some groupers and grunts were depleted quickly (Menasveta 1980). Sharks have largely disappeared from southern China due to fisheries that once focused on them (Lam and Sadovy 2011). This was especially the case for species which were also fished by other fisheries in habitats not accessible by trawling. For example, groupers are commonly taken as juveniles in estuaries (via various types of nets), as sub adults on coral reefs (via gillnets or lines) and large, breeding age fish that inhabit untrawable, deeper reefs can be fished by traps and lines or have particularly high catchability when taken in their spawning aggregations (Sadovy de Mitcheson et al., 2017). Serious depletions have also occurred in the large yellow croaker, Larimichthyes crocea, once one of the four biggest fisheries in China; this was heavily due to fishing on their spawning aggregations, ineffective management and ineffective restocking (Liu and Sadovy de Mitcheson 2008).

As mentioned above, the preferential removal of some species groups changed the structure of fish communities. In the Gulf of Thailand, in the early years, the removal of higher order predators created an increase in middle order predators, which were then quickly fished. This resulted in a proliferation of smaller, lower trophic level, species that were able to handle higher levels of fishing pressure. Early estimates of sustainable yield (see below) were quickly exceeded and catches of high value, low trophic level, species such as shrimps and squids continued to climb, as did the catch of low value species (so called trashfish).

The situation in the Gulf of Thailand was repeated elsewhere in the region. Malaysia experienced a rapid decline in catch per effort in some areas (Abu Talib et al 2003). Manila Bay, in the Philippines became a type case for those with an interest in the consequences, both ecological and economic/social, of unrestrained fishing effort expansion in tropical environments (Silvestre et al 1987). Hong Kong suffered a major depletion in fish stocks (Cheung and Sadovy 2005; Morton 2005), as did mainland China (see below) and Vietnam (see below). As a consequence of these depletions there were some major conflicts between fisher groups (e.g. Purwaningsih, et al 2011 and Adrianto et al 2007 for Indonesia, and Cho 2012 for Korea) but, as mentioned in above, there were also benefits to the processing sectors, especially women, who dominate the workforce in processing companies.

This complex mix of the ecological attributes of the species-rich marine communities and the ability of user groups to make productive use of whatever was caught made for some major challenges in assessing what the potential yields could be, determining acceptable trade-offs between ecological, social and economic needs and putting in place viable management measures to ensure future viability of the natural resources being exploited.

5.1.2 Managing multi-species fisheries

Whilst a major driver of the depletions was the lack of any effective controls on fishing effort, an underlying contributor was the nature of the stock assessments that informed government policy. For single species assessments, for example, the sheer diversity of species involved in the fisheries made researching the main biological parameters controlling their collective productivity almost impossible. In addition, the reality was that most fishing activities were too unselective to only take one species and thus fishery scientists had to deal with species complexes which, in some circumstances involved dozens, if not hundreds of species (in the case of trash fish) and this had some significant consequences as explained below.

It is worth recalling at this point that the development of modern fisheries science originally took place in high latitude countries that typically had a small number of species, some of which were extremely abundant, such as cod, pollock, haddock etc. In seeking to gain an understanding of how many fish could be taken on a long term, sustainable basis, fisheries scientists developed tools that generated estimates of sustainable yield on a species (or even stock) basis (see for example Hoggarth et al 2006). Developing an estimate of the sustainable yield from a stock was determined on the basis of the biological characteristics of the species/stock, some basic assumptions about stock characteristics (such as density dependent responses and poor stock-recruitment relationships), and the nature of the fishery with little regard for the wider role of that species/stock in the marine ecosystem, such as the needs of predators or the potential interactions with competitors.

These tools became increasingly sophisticated as more data from field studies were gathered but the general approach of seeking to define sustainable catches by single species/stocks became incorporated into regulation and laws at jurisdictional level and also in international laws and agreements. This occurred even despite the well-known challenges associated with having a fishery operating on one species/stock but that may be affecting species utilised by another fishery. Other consequences of seeking to maximise the yield from a desirable stock related to the potential depletion of other species caught in the same fishery or, conversely, leaving underfished stocks in the water. The latter was perceived to have undesirable social and economic consequences but, as became apparent later on, could also have undesirable ecological consequences in some circumstances as well (Garcia et al 2012) and certainly into the long term without management.

Whilst the challenges of multispecies and multi-stock fisheries were known in the 1950s there was little progress made on developing the tools for understanding and managing them, or for factoring in the wider ecosystem until much later. In the 1960's, when developing countries in the tropics were seeking to develop their fisheries, it became clear that seeking to develop species-by-species estimates of yields was, except in a few circumstances (mainly high volume species), simply not possible.

Notwithstanding the variety of single species assessment tools that have been applied over the years the biggest influence on the current state of many fisheries is the application of aggregate yield models which have been widely used in the wider Asian region over many years to provide estimates of sustainable yield. Three key approaches have been applied, depending on what type of data/information is available:

1. In the absence of any survey or catch data, estimates of fish density per unit area can be based on existing information from similar habitats or ecosystem types in other parts of the world (see for example Gulland 1971).
2. Research surveys were used to generate estimates of the available biomass per unit area. For trawl fisheries this involves measuring the catch in trawl shots in the area of interest and then extrapolating the tonnage taken to generate an estimate of standing stock for the entire area. Correction factors such as the selectivity of the net and the catchability of the species (amongst other factors) need to be considered. Such techniques are used in the absence of any reliable CPUE data from fishing activities. Once the biomass estimates are available then estimates of Maximum Sustainable Yield can be generated (see for example Gulland 1971, 1983) where $MSY=0.5*M*B_0$. It is assumed that the surveyed biomass is unfished and that natural mortality - M - for small pelagics is 1 and for demersal species M is 0.5. This results in MSY estimates of 50% of standing biomass for small pelagics and 0.25 % for demersal fish.
3. A third commonly used method is applied when it is possible to collect catch and effort data from a fleet that is fishing the area of interest. Using models developed by Fox (1970) and/or Schaeffer (1957) (and modifications thereof) the MSY is determined to be the point where CPUE is highest. Such models, which were originally developed for single species/stocks, have been regularly applied to multispecies situations where the total biomass (of all species) is plotted against effort.

Option 1 was only ever considered for scoping purposes in the very early days of planning for fishery expansion (when such planning did take place). Options 2 and 3 help narrow down the estimates, although there are significant potential sources of error. Option 2 was used in some countries to provide indicative yields for fishery planning purposes (see below for Thailand and Vietnam). Option 3 was, and continues to be used as a management tool.

The use of aggregate yield models has been subject to debate for decades, as it became clear that multispecies fisheries presented very significant challenges to fishery managers due to the information demands and the uncertainties confronted; particularly in developing countries located in the tropics. In 1983, noted fishery scientist, John Gulland said in a presentation to the South East Asian Fisheries Development Centre, on behalf of the FAO:

> *Another situation that is relatively easy to analyse is when a single fishery takes a great variety of species, without being directed at any one particular species. This is the situation in many trawl fisheries in the tropics or sub-tropics. Here it may be possible to treat all the fish together as a single stock- Then the production model approach can be followed, relating the catch and catch per unit effort to the total effort. Species differ in value, and the effect of heavy fishing on the fish communities is often to change the relative abundance of different species – often though not always in the direction of increasing the relative abundance of the smaller and less valuable species.*

Some ten years later, two other leading fisheries scientists, Ray Hilborn and Carl Walters stated that:

> *"Furthermore, in many fisheries, again tropical ones especially, the catch consists of many species, and the catch data are difficult if not impossible to collect by species. Management regulations are also difficult to make species specific. In these circumstances, treating the entire catch as a biomass dynamics pool may be more appropriate than trying to look at single species dynamics. (Hilborn and Walters 1992, p. 298)*

Such pragmatic views attracted criticism from other senior scientists (e.g. Pauly 1987, 1988, Sparr and Venema 1998), who explained the decline in the fish stocks in the Gulf of Thailand as a consequence of the inappropriate application of single species approaches to multispecies fisheries.

As increased attention was paid to threatened species, biodiversity conservation and ecosystem health (Ecosystems Based Management of FAO, biodiversity consideration under the Convention of Biological Diversity, etc.), the need grew to consider the entire ecosystem and reduce serious threats to those species with life histories that make them particularly vulnerable to fishing.

The challenge of how to evaluate, make decisions about and control such fisheries dogged regional governments for decades. More sophisticated tools such as multispecies VPA models (see references in Sparr and Venema 1998) and the BEAM models (see Hoggarth et al 2006 and references therein) were developed. All of these tools have been widely used both inside and outside the region, with their application in the region based on advice and the provision of training materials from international fishery bodies such as a FAO. BEAM5 has been applied to the Gulf of Thailand (Willmann 2007).

Such an approach reflects the circumstances in which fishery scientists and managers find themselves facing:

1. The wide variety of species present makes large numbers of species assessments virtually impossible.
2. The need to access the most productive species in order to benefit the largest numbers of people and generate revenue for development.
3. Capacity issues in terms of staffing and availability of expertise, which may limit the resources that can be allocated to conducting stock assessments across multiple species on a timely and regular basis and monitoring fisheries.
4. The challenges of separating species in catches, which can make species-based assessments impractical to implement in terms of management.
5. Managing any more than a small number of species at their own MSY is not protective of the ecosystem (Walters et al 2005).
6. The challenge of losing the more vulnerable species if you go for the average – leads to threats to the more vulnerable species in the ecosystem (Pikitch et al. 2004).

Fitting Fox or Shaefer type production models to aggregate catch total catch data from a fishery is an empirical approach that attempts to summarise the changes in ecosystem structure (e.g. species composition, size composition and the relative abundance of different trophic levels) and productivity over the history of the fishery. This includes, for example, the dynamics of 'productivity release' in prey populations as their predator populations are reduced. These changes are expected to depend on the pathway of fishery development, including the history of fishing effort by different gear types because this determines the fishing mortality applied to different parts of the ecosystem and consequently the types of ecosystem responses that are triggered. As a result, interpretation and estimation can be complicated if the data span only part of the fishing history, if change in the selectivity of fishing during the course of fishery development cannot be well represented in the analysis, if a lot of catch is unreported or illegal, or if there is need to predict the consequences of new or previously unobserved fishing patterns.

A further issue, common to all multispecies fisheries however the overall aggregate maximum yield is estimated, is that the level of fishing that gives the maximum aggregate yield will under-fish some species and over-fish others compared to the maximum sustainable yield of the individual species. A generalised illustration of this is shown in Fig 44.

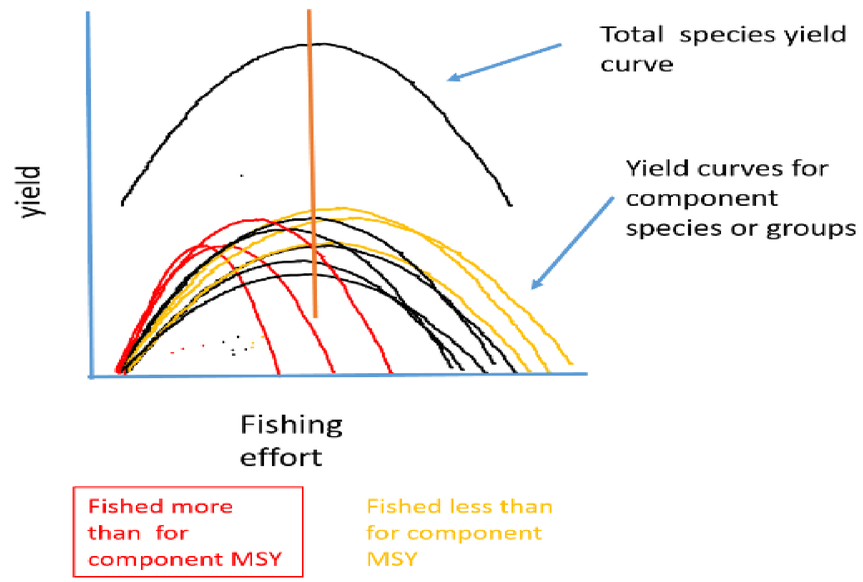


Figure 44 – stock responses to increasing fishing effort at a given level of selectivity (Sainsbury 2017)

Whilst there are always trade-offs in exploiting natural resources, there may need to be protective measures put in place to ensure that vulnerable or already-threatened species are not put at risk of serious reproductive impairment, even if they are maintained at levels beyond MSY.

An overarching question, from a policy and legal perspective, is whether aggregate yield approaches are consistent with the requirements of the UN Law of the Sea. This aspect is considered in more detail below.

Thailand relies on an aggregate yield model (Schaeffer) as the basis for its fisheries management plan which aims to cut capacity back to a level consistent with model estimates of 90% of MSY (Anon 2014). Vietnam makes use of the Gulland model and Schaeffer models to provide management advice.

5.1.3 Stock assessments

A wide variety of assessment techniques have been used over the years (FAO 2010a, 2010b). Early estimates of sustainable yield for the demersal stocks in Thai waters of the Gulf of Thailand were generated in 1969 by Gulland (400 000t), 1972 by Gulland (based on data from Menasveta) (500

000t), Isrankura in 1969 (500 000t) and then in 1973 by Shindo (715 000t) (all quoted in Menasveta 1980). Panayotou and Jetanavanich (1987) quote studies from 1973 claiming the sustainable yield was only 447 000t (waters down to 50 m depth). At the time the waters of Thailand were claimed as being to a depth of 50 m. Gulland's 1968 estimate also included another 250 000t for the coasts of Cambodia and Vietnam and another 250 000 to 400 000t for the central Gulf (depths greater than 50m). Menasveta (1980) does not set out the basis for the calculations of Gulland's 1968 estimate but, at the time, there would have been both research trawl and some commercial CPUE data available. In addition, it is unclear whether the estimate of Shindo was for the whole Gulf or just Thai waters down to 50m. Nevertheless he claimed that catches had exceeded MSY since 1966/67 and that measures for the conservation of the demersal fish stock in the Gulf should be taken without delay.

In addition to the demersal stocks it was estimated that potential yield of the pelagic stocks was of the order 380 000t (Menasveta 1980). Taking the second of Gulland's estimates and including the waters of Thailand, Vietnam and Cambodia plus the estimate of pelagic yield the total potential yield was almost 1.8 million tonnes, which was equal to the estimates of virgin biomass for the entire Gulf (references in Panayotou and Jetanavanich 1987). Estimates changed over time, possibly as a result of better data but also due to changes in the species composition which favoured more highly productive species as a result of fishing pressure. Boonyubol and Pramokchutima (1984) estimated the potential yield at 750,000 metric tonnes per year at 8.6 million hours of fishing effort. Boonwanich quoted in AUEP (2007) estimated a maximum sustainable yield of demersal resources at 893,000 metric tonnes, with optimal fishing effort levels of 22 million hours (references quoted in UNEP 2007). Estimates of yield not only depended on what area was under consideration but also mesh size. The DoF's research vessel used larger mesh size (4cm fixed) than commercial vessels (variable 2.5cm or less) and yield estimates were lower. In addition to the aggregate yield assessments the Thai Department of Fisheries has also undertaken a number of species based assessments over the years. Kongprom et al (2003) document the major increases in exploitation ratios F/M for 23 species of invertebrates and fish, both demersal and pelagic, over the period 1971 to 1995.

The situation in Thailand is very well documented and illustrates a wide variety of challenges for the conduct of stock assessments and generating estimates of MSY that undoubtedly apply to other countries in the region.

For Vietnam, information is less or at least less available. As mentioned above, Gulland's 1968 estimate included 250 000t for both South West (Gulf of Thailand coast) Vietnam and Cambodia. According to data (from 1974 or earlier) quoted in Panayotou and Jetanavanich (1987) the standing stock for the area offshore the Mekong Delta (236 000 km sq) was 1.383 million tonnes with a potential yield of 553000t. Thuoc (2000) estimated the total standing stock of Vietnam's marine fish to be 3.3 to 3.5 million tonnes creating a potential yield of 1.5 to 1.6 million tonnes. Son and Thuoc (2003) partitioned the estimate of biomass in to about 2 million tonnes of pelagic species and 1.4 million tonnes of demersal fish with the rest being comprised of other species such as crustaceans.

Nguyen (2005) reviews a number of studies from the Gulf of Tonkin (northern Vietnam adjacent to China) at various times (1959 to 1962, 1979 to 1988, 1990-1998, 1996 onwards and his own work in 2001 to 2004). These studies may have included both demersal and pelagic stocks or just one type and they may have included more than just the Gulf of Tonkin.

Daug et al (2002) used a research trawler to survey the waters in the northern, central and southern (only the southeast) parts of Vietnam at several depth strata (two in each of the north and central region and three in the south) over two years, which covered the monsoon and dry seasons. All of these factors had an influence on estimates of standing stock but, overall, the estimate for the depth zone 20-200m depth for the east coast of Vietnam was 700 000t. Hasan et al (2000) surveyed the pelagic resources of the coast (including the south west) out to the limits of the EEZ using sonar and calculated that the biomass was an estimated 9.26million tonnes.

Ha (2009) reported on the biomass of key surimi species based on a survey of all trawlable gounds in Vietnam in 2004 and 2005. The biomass estimates for 2005 were aggregated across species (within groups) and were listed as follows – lizardfishes (57 000t), threadfins (30 000t), croakers (18 000t), goatfishes (17600t) and bigeye snappers (37 000t). The largest biomass was in the southeast of Vietnam which has the largest area of trawlable continental shelf.

Ha and Nguyen (2017) reported on coast wide trawl surveys undertaken in 2013 and 2016. For the northeast monsoon period in 2016 the demersal biomass estimates for the south east (190 000 sq klm) and south west (92 000 sq klm) were approximately 216 000t and 159 000t, respectively. The comparison of the estimate provided above (Panayotou and Jetanavanich 1987) of 1.383 million tonnes for the south east and this latest estimate is stark although whether the 1974 estimate is just for demersal species or includes pelagic species as well is unknown. For the southwest the estimate for the 0-50m depth strata was about 100 000t which compares to Gulland's 250000t for the same depths, but for Cambodia and Vietnam combined.

For China stock assessments have been conducted for several key species of fish taken variously for both food and trash (Tables 24 and 35) showing many stocks to be depleted or overexploited.

*Table 34 Over-exploited, declining or depleted fish species identified in feed fish samples (Zhang et al., submitted; Greenpeace-China 2017). Note: * Stock information only available at Genus (spp.) level. † BS: Bohai Sea, YS: Yellow Sea, ECS: East China Sea, SCS: South China Sea, NSCS: northern South China Sea, NWP: North west pacific. †: Category I: Commercially important species; Category II: Forage species; Category III: Mixed species.*

No.	English name	Scientific name	Stock status information in references†	Catch categories†
1	Conger pike	*Muraenesox cinereus*	NSCS: depleted, over capacity (44); YS: over-exploited ((45), page 31); ECS: catch volume declined, size became smaller ((18), page 305)	I
2	Chinese herring	*Ilisha elongata*	NSCS: depleted and over capacity (44); YS and ECS: over-exploited, resource declined to almost depleted ((18), page 295; (45), page 31; (46), page 305)	I
3	Commerson's anchovy	*Stolephorus commersonnii*	NSCS: over-exploited and over capacity (44) (as "Anchovies, *Stolephorus* spp." in FAO report); ECS: over-exploited (47)	II
4	Indian anchovy	*Stolephorus indicus*	NSCS: over-exploited and over capacity (44) (as "Anchovies, *Stolephorus* spp." in FAO report); over-exploited (47)	II
5	Japanese anchovy	*Engraulis japonicus*	NWP: fully exploited (48); over-exploited (47); YS: resource decreased (18), page 165-166; (46), page 278; (49), page 588);	I

			ECS: overfished, resource declined ((18), page 165-166; (46), page 278; (49), page 588)	
6	Greater lizardfish	*Saurida tumbil*	NSCS: over-exploited and over capacity (44); SCS: overfished, need protection ((18), page 409; (49), page 326)	I
7	Slender lizardfish	*Saurida elongata*	ECS: over-exploited (47)	I
8	Japanese scad	*Decapterus maruadsi*	NSCS: over-exploited and over capacity (44); SCS: resource declined in the 1980s, measures have been taken, and the resource has been recovered a bit ((49), page 638-650); resource declined ((18), page 404); over-exploited (47);	I
9	Jack mackerel	*Trachurus japonicus*	NSCS: fully exploited and over capacity (44); NWP: fully exploited (48)(47); SCS: resource declined ((18), page 407); ECS: resource declined ((46), page 256)	I
10	Threadfin bream	*Nemipterus virgatus*	NSCS: over-exploited and over capacity (44)	I
11	Threadfin	*Evynnis cardinalis*	NSCS: over-exploited and over capacity (44), ((49), page 802)	I
12	Croaker	*Pennahia* spp.*	NSCS: over-exploited and over capacity ("Silver croakers, *Pennahia* spp." in FAO report include at least three identified species: Big-head pennah croaker (*P. macrocephalus*), Donkey croaker (*P. anea*) and Silver croaker (*P. argentata*))	I
13	Croaker	*Johnius* spp. *	SCS: over-exploited ((49), page 859) ("*Johnius belangerii*." in the report may include other *Johnius* spp. such as: Caroun croaker (*J. carouna*), Sharpnose hammer croaker (*J. borneensis*), Trewavas croaker (*J. trewavasae*), *J. distinctus*, and *J. grypotus*)	I
14	Large Yellow Croaker	*Larimichthys crocea*	NSCS: depleted and over capacity (44); ECS: resource decreased seriously ((46), page 286)	I
15	Yellow Croaker	*Larimichthys polyactis*	NWP: fully exploited (48); BS, YS and ECS: overfished, resource declined ((18), page 75, 182,299; (49): page 701; (46): page 170-183; (45), page 31)	I
16	Mi–iuy croaker	*Miichthys miiuy*	NSCS: depleted and over capacity (44)	I
17	Goatfish	*Upeneus* spp. *	NSCS: depleted and over capacity (44); ("Goatfishes *Upeneus* spp." in FAO report include at least three identified species, Deep-water goatfish (*U. subvittatus*), Sulphur goatfish (*U. sulphureus*), and Japanese goatfish (*U. japonicus*))	NA
18	Japanese grenadier anchovy	*Coilia nasus*	Yangtze Estuary: overfished and depleted (50)	I
19	Japanese Spanish mackerel	*Scomberomorus niphonius*	BS and YS: fully exploited ((18), page67, 169, (19), page 124-125;); ECS: overfished ((18), page 293; (46), page 272)	I
20	Chub mackerel	*Scomber japonicus*	NWP: fully exploited (48); fully exploited (47); need to reduce fishing effort and protect the juveniles ((19), page 166; (49), page 637; (46), page 218)	I
21	Largehead hairtail	*Trichiurus lepturus*	NSCS: over-exploited and over capacity ("Hairtails, *Trichiurus* spp." in FAO report); NWP: over-exploited; BS, YS and ECS: overfished, resource declined seriously	I

			((18), page 192, 423; (19), page 129: resource depleted; (46), page 169; (49), page 663-680)	
22	Pacific rudderfish	*Psenopsis anomala*	SCS: resource declined seriously ((49), page 635)	I
23	Silver pomfret	*Pampus argenteus*	NSCS: depleted and over capacity (44) ("Pomfrets, *Pampus* spp. in FAO report); ECS: overfished ((18), page 292; (46), page 198)	I
24	Pomfret	*Pampus* spp. *	NSCS: depleted and over capacity (44) ("Pomfrets, *Pampus* spp.' in FAO report include at least two identified species: Chinese silver pomfret (*P. chinensis*), and *P. punctatissimus*)	I
25	Bastard halibut	*Paralichthys olivaceus*	BS and YS: overfished, resource declined to almost depleted ((18), page 188; (19), page 172; (49), page 758)	I
26	Flounder	*Pseudorhombus* spp. *	NSCS: depleted and over capacity ("Flounders, *Pseudorhombus* spp." in FAO report include at least one identified species: Cinnamon flounder (*P. cinnamoneus*))	I
27	Ridged-eye flounder	*Pleuronichthys cornutus*	YS: overfished, resource declined ((18), page 188; (49), page 759)	I
28	Common hairfin anchovy	*Setipinna tenuifilis*	BS and YS: resource declined ((18), page 64)	I

*Table 35 Fully exploited, declining, fish species identified in feed fish samples (Zhang et al., submitted; Greenpeace-China 2017). Note: * ECS: East China Sea. †:Category I: Commercially important species; Category II: Forage species; Category III: Mixed species.*

No	English name	Scientific name	Stock status information*	Catch categories†
1	Pacific sandlance	*Ammodytes personatus*	Moderate exploited (47)	II
2	-	*Pholis fangi*	Fully exploited ((19), page 134)	III
3	-	*Acanthogobius hasta*	Resource decreasing ((19), page 174)	I
4	Bombay-duck	*Harpadon nehereus*	ECS: moderately fully exploited (47)	I

In a scenario analysis of the fisheries of the South China Sea, Sumaila and Cheung (2015) found found that the combined effects of unsustainable management and the impact of climate change would lead to further erosion of the valuable resources of this important marine ecosystem. This erosion is projected to have deep food security, ecological sustainability and financial consequences both for businesses and individuals, as revenues to the former drop while individuals face high prices with declining catches. The report's findings suggest the need to immediately take action across all sectors of the community: governments, regional organizations, businesses, civil society and individuals. The national governments of countries in the SCS need to work, both individually and collectively with the international community, to immediately and substantially reduce CO2 emissions. They need to significantly improve the management of their fi sheries by eliminating harmful subsidies, such as those for fuel, and by investing in science and monitoring activities to address IUU fi shing. Private actors (businesses, NGOs and individuals) need to make a conscious effort to reduce their carbon footprint and to source the food they eat from sustainable suppliers.

6 SECTION 6

6 6.1 Discussion

Trawling is a widely used method of catching a huge variety of marine organisms. Trawls can be used to take animals living on the seabed or in the water column and their efficiency has resulted in their rapid proliferation throughout the world, including China, Vietnam and Thailand, where trawls are responsible for about 50% of total seafood production (FAO 2014). The sector supports an enormous network of dependent businesses that supply human food and animal feed (especially feeds for aquatic organisms like fish and shrimp). However, with this efficiency, and lack of fishery controls, comes a high potential for overfishing and other forms of damage to the marine environment and there is abundant evidence that this potential is being realised on a vast scale.

Across the major 'trash fish' (in the very broadest sense of the word meaning low value mixed species not going to direct human food) producer countries, while volumes varied widely by fishing location, season and depth from very low to very high percentages, overall the average trash fish proportion by weight in trawlers regularly exceeded 50% of the total trawler catches. This highlights the massively important role that this component of trawler catch plays in the region's economy and ecology. Given that trawlers may account for approximately 50% of total seafood production in the region, this would suggest that trash fish can regularly account for more than 25% of the total national catches. Clearly it is a major fishery sector that urgently needs serious attention.

Moreover, given that trash fish catches are often not documented, much less described in detail in terms of species and abundances, these catches likely form a large proportion of the 'unreported' catch highlighted in the Boom and Bust report (Sumaila and Cheung 2015) an update of which this report is contributing towards.

The information in this report in addition to the high percentage of trash fish in trawler catches in particular and national catches generally, contains some recurring themes, namely;

- The ubiquitous nature of trawls as a major fishing method and as a major source of feed fishes and, to a much lesser extent, invertebrates;
- The high degree of uncertainty generated by the general lack of data and information (except, perhaps, for Thailand);
- Where data do exist there is enormous variability in the nature of catches and associated impacts;
- Where data do exist there is a high level of juvenile capture of a diverse range of species (including those of direct food importance, the food of such species and, in China, species from restocking programmes);

- The existence of complex and far reaching supply chains that feed value-added sectors which support hundreds of thousands of people;
- Variability in the level of achievement of fishery reforms by the countries of interest with many regulations but often poor compliance or limited enforcement;
- The urgent need for research to develop feeds not so heavily dependent on fisheries and culture species not so dependent on wild fish feed;
- Various levels of IUU and threats to marine biodiversity (both target and non-target specis), and
- The urgent need for fishery managers to set clear management objectives and to manage. This includes improved participation in relation to international agreements and commitments such as those on biodiversity and responsible fisheries.

6.1.1 Distribution of trawling

Our study focuses mainly on three countries in Asia, those that are the major suppliers and/or users of trashfish, but trawling is widespread and there is evidence that the types of impacts documented in China, Vietnam and Thailand, are also to be found in other countries. According to FAO (2014) there were an estimated 80 000 trawls in use in the region (as covered by the Asia Pacific Fisheries Commission). The uncertainty that underpins knowledge about the number of vessels underpins almost all aspects of understanding the scope of the industry and its impacts, both positive and negative.

At a coarse level of resolution trawling can be found along the continental shelves of the three countries we examined in detail. Inshore, shrimp trawls dominate and, unless controlled by legislation, these can also be found in the estuaries in the form of either beam or otter board trawls. Most fish trawling occurs further offshore where it may be restricted by natural controls such as major reefs or by seasonal access factors such as the monsoon periods. By and large regulatory controls over area access are minimal but there is commonly some separation between fleets aimed at keeping larger vessels away from the inshore areas. For example, in the Gulf of Thailand the inshore zone (from the shore out to 5 nautical miles) is banned for trawling and Malaysia and Vietnam also spatially separate non-trawl and trawl zones and larger from smaller vessels.

At a finer level of resolution there is currently little available information on what areas are trawled and this has implications for understanding interactions between (demersal) trawling and seabed biodiversity. Thailand has mapped the major areas in the Gulf of Thailand and may soon be in a position to conduct finer scale analyses as a result of the growing use of Vessel Monitoring Systems (VMS), as will neighbouring Malaysia. The situation is potentially the same in China where VMS devices have reportedly been widely installed (Wang et al 2012) and the areas of interest to the trawl fleet in the South and East China Seas (Zhang et al 2016) amount to less than 50% of the area open to trawling. Vietnam has also been mapping the location of fishing effort amongst its fleets but published information is not available.

As fuel costs increase (especially if subsides are reduced) fishermen will focus more on the known productive areas which presents opportunities for habitats to be set aside from trawling. Its unclear whether habitat mapping has been undertaken at a suitable scale and we have found no evidence of a structured approach to the establishment of a Comprehensive and Representative Reserve

System. However, the overlaying of habitat mapping with trawl locations may well reveal areas that have not been subject to benthic modification and thus be suitable protected areas.

6.1.2. Uncertainties driven by lack of data/information

We have attempted to evaluate the trawl fisheries in terms of production and by usage of the catch. Unlike many trawl fisheries outside of Asia there is very little documented discarding as almost all the catch is used. However, there is also little evidence of observer coverage on vessels and, in some areas where carrier vessels are used to ferry the catch to shore it may well be that high-grading (dumping of lower value material as higher value material comes on board) is occurring. Nevertheless, given the fact that the European Union has only recently moved to a no-discard policy for its fleets and discarding remains common throughout the world the fact that China, Thailand and Vietnam practice has some positive aspects to it. However, without management, this approach too leads to or worsens overfishing. Indeed, the increase in industries that are based on former discards creates a situation is created whereby fishing becomes even harder to stop or acts as a disincentive to avoid discards/bycatch by developing appropriate technology. The extreme case is like that of Hong Kong where shrimp fisheries declined, trash fish/former discards gained value for fish feed and enabled trawlers to continue fishing until the situation became so bad that the city banned trawling. In this case the city was wealthy enough to compensate fishers who had trawlers and also in a position to import its seafood (currently importing about 90%). Other countries may not be able to do this.

Thailand collects comprehensive information on its fishing fleets. Records are kept on landings by main port and the department of fisheries also conducts regular, independent surveys of stock abundance. Given the high species diversity there is, by necessity, some aggregation of information into species groups and the research trawls use a larger mesh size in comparison to commercial trawls which generates a difference in perceptions about the status of the fishery in that fishermen catch larger volumes of smaller fish than the research trawls (Panayotou and Jetanavanich 1987). Landings are publicly reported on a regular basis and the department also has a large collection of data which it is able to analyse and use for management purposes. The situation in Thailand compares well to Vietnam and China where landings data is difficult to obtain and scientific surveys less frequent. Guo et al (2008) set out the data collection system in China and it appears that data collection may be more comprehensive at the provincial level but aggregation occurs and some granularity is lost. However, is also likely, given the diverse and mixed nature of the catches that species by species information is simply impossible to collect other than by targeted studies as attempted by ourselves and by Greenpeace-china (2017).

Part of the issue associated with the collection of fishery level data is that management plans are either non-existent and/or do not have clear objectives. There is a variety of ways of aggregating data (by indicator species, by trophic level, by volume, by importance etc) which could feed into monitoring the performance of the fisheries against management objectives. Without some clarity over what species or groups need to be monitored from a resource management or conservation perspective it is difficult for stakeholders or government to make claims about whether these fisheries meet international norms in regards to law or policy. A lack of fishery objectives at the regional or national makes management planning very difficult.

In terms of the post harvest use of the catch it is challenging to get a clear understanding of the disposition of catches in a detailed way, with the possible exception of fish destined for surimi where trawls are the most common mechanism for taking the species of interest. For a number of food species such as snappers, groupers and many small pelagics there may be multiple gear types involved and unless catch-by-gear data are recorded (as occurs in Thailand and Malaysia) then gaining a full understanding of the role of particular gears in supply chains is impossible. The situation is even more complex for the fishmeal sector as this product is manufactured from material from a variety of sources including domestic wild harvest (via various gears such as trawls and purses seines) and processing wastes from domestic, imported and aquaculture production. Equally complex are other processed product supply chains such as dried, salted, smoked and fermented products (such as fish sauces) which involve a wide variety of species from multiple gear types. Fishery of origin information is lost along complicated supply chains and during product transformations. Information on international trade in trash fish or fish meal is poorly resolved.

At a very broad level trawling accounts for about half of the 23million tonnes of wild harvest seafood in the region. We estimate that in China that out of the 4.3m tonnes of trawl caught material about half is used for direct human food and half for fish/animal feed with a very small proportion used for processed human food. This is very different to the situation in Thailand where about 25% is used for fish feed. The situation in Vietnam is unclear but the feed proportion can be high.

The terminology applied to catch components has been one source of the lack of clarity as to usage of the catch. The term 'trashfish' has been applied in different ways in different countries. In Thailand it has been used to cover fish that are unsuitable for human consumption due to poor handling or inedibility. In Vietnam it covers any fish that are destined for fish/animal feed whereas in China there is also consideration of the term 'low value' fish as separate from trash fish. Our study found very little low value fish in comparison to a previous study (Grainger et al. 2005) and whether this is simply due to the sampling regime (e.g. time of year, ports sampled, landings sites sampled), increasing demand from the animal feed sector or some other factor is unknown.

Irrespective of definitional issues it is clear from our study and from previous studies that the amount of fish destined for feed (either directly or indirectly via fish meal) comprises a very variable proportion of the catch depending on time of year (especially monsoon versus dry seasons), gear type (pair trawling, otter trawling – shrimp and fish, beam trawling), location, depth and degree of development of the industry. In regards to the latter the proportion of trashfish (for fishmeal) in Thailand has, over the past few decades declined from 50% of the catch to 25% of the catch as more fish is used for higher value human food usages. In China, our study found that fish for feed is currently about 50% of the trawl catch.

6.1.3 Overfishing is widespread

There is abundant evidence of overfishing from across the region. Some species are exploited by a wide variety of fishing gears at all stages of their life cycle (adults, sub adults, juveniles and even larvae). Our study documents 26 overfished/depleted species in the Chinese trash fish component alone (we did not study the human food component), echoed by Greenpeace-China (2017).

Overfishing is also commonplace in Thailand but it should be noted that for many of the species that are known to be overfished the data are, in some cases, several decades old. While aggregate yield analyses are more up to date in Thailand, individual species are generally not. Thailand landings data is very up to date and there is up to date analysis of catch composition.

In the few cases where fisheries have been well documented since inception the speed of depletion of the standing biomass was quite rapid. In the Gulf of Thailand concerns were being expressed about overfishing some ten years after the fishery began. The growth in the number of vessels was far from controlled and, even though there were estimates of sustainable yield available, advice regarding the need to control the number of vessels was simply ignored. This is not a situation unique to Asia nor developing country fisheries and many countries have spent decades trying to reduce excess fishing capacity that accumulated during the early development phase of a fishery, trawl or otherwise. Excessive capacity is a global problem and one that is particularly problematic in Asia where there is a degree of reliance of coastal communities on fisheries and this makes reform politically sensitive. Nevertheless, it is the role of fisheries management agencies to make the tough decisions if they are to meet both international expectations and domestic law.

We have not attempted a root cause analysis of the causes of overfishing in the trawl fisheries nor the wider fisheries of Asia. There is an abundant literature on the generic factors commonly involved in driving overfishing and regional governments are signatories to commitments to action for two of the key factors – Illegal, Unregulated and Unreported (IUU) fishing and excess fishing capacity. Countries need to find ways of removing, not relocating excess fishing capacity. Governments have responded to crisis such as overfishing or conflict between user groups by declaring closed areas or banning gear types without any consideration for the consequences of transferring the fishing effort into other areas or gears. Indeed, such drastic actions have commonly been accompanied by subsidies for moving into other fisheries. Experience in other countries has found that unless access to other fisheries/areas is tightly controlled or subsidies addressed the benefits of change are quickly eroded.

Cutting back the fishing pressure will enable progress on one of the major issues associated with fisheries in the region, including the trawl fisheries; in particular the excessive take of juvenile fish needs to be addressed. Our study confirms findings in other studies in China, Vietnam, Thailand and others, where the high proportion of juvenile commercially important species has been a source of concern for many years and a major contributor to the overfishing problem. At present, fishermen are increasingly dependent on every fish that comes onboard due to poor catch rates and, as such, requiring increased mesh sizes will face stiff resistance, as occurred in Malaysia where moves to increase mesh sizes took some 38 years to bring into law. The current system, which has failed to control capacity, simply breeds desperation, lack of compliance with the law (inadequate though these seem) and an inability to accommodate the short term drops in catches required to make the transition to a more sustainable exploitation regime.

6.1.4 Countries at different stages of the development and management process

One of the benefits of reviewing the circumstances across countries has been gaining an appreciation of the differences. The fishery in the Gulf of Thailand started in the early 1960's and has been through various changes over the years arising from overfishing, ecosystem alteration, changes in main products and, now, a major effort to rebuild stocks and cut fishing effort. The fishery originally began as an inshore shrimp fishery but expanded offshore to focus on fish as well. The fish meal sector grew in the 1970's in response to efforts to find a use for the large quantity of bycatch produced, and benefited from the 'release of predation' effect. The decline in demersal resources resulted in changes to the fishery which yielded an increase in catches of pelagic resources by both purse seining and pair trawling. It also led to the government encouraging Thai vessels to fish outside of Thai waters, an initiative that simply spread the excess effort into neighbouring countries and creating tensions that persist to this day, despite the declaration of 200nm Exclusive Economic Zones by these countries.

Policy commitments to full utilisation and efforts to develop new products created the surimi sector which required better quality fish and this diverted supply from the fish meal sector but encouraged ongoing fishing. The current stage of development is seeking to rebuild stocks and crack down on illegal fishing.

Vietnam's development was delayed by a couple of decades due to war but it experienced a rapid development in the fleets followed by depletion of resources, especially inshore. The government facilitated a move offshore which also created overfishing and tensions. The vessels that returned inshore were much larger which made the overfishing problem worse. The government is currently reducing effort inshore and shifting effort offshore (again) but it has also begun the process of bringing in management. Vietnam also makes full use of catches with various processed products (frozen, fishmeal, surimi, sauces etc).

The shift in usage of fish from low to high value is not uncommon. Chandrashekar et al (1978) refer to threadfin, *Nemipterus japonicus*, as 'trashfish' whilst proposing a novel pickling method to increase its value in India. This species is now highly sought after for the production of premium grade surimi for the Japanese market and is an important and well-considered food fish in some areas.

Indonesia took a slightly different path but with similar outcomes. The trawl ban of 1980 shifted effort (via subsidies) into shrimp farming, the purse seine sector and vessel construction. The repurposing of trawlers as purse seiners substantially increased effort in this sector which resulted in depletion of pelagic resources but at the same time the trawl sector morphed by modifying the gear to make it legal and again grew out of control. Unlike Thailand and Vietnam, whilst Indonesia has a processing sector, it does not have a large fishmeal sector utilising trawl bycatch. Prior to the trawl ban there had been some growth in the fishmeal sector but this declined after the ban although it does have some fishmeal production from small pelagics, which in other countries are used for human food. Indonesia now imports most of its fishmeal to supply its important mariculture industry. Indonesia has been considering another trawl ban and shifting effort into the gillnet sector but efforts to control overall catches have been slow.

The literature is replete with examples of the problems caused by open access fisheries where there are no controls on how many vessels may be involved. The issues are independent of gear type and examples can be found for longlines (demersal and pelagic), gillnets, various types of seines and others. The issue is not restricted to industrial fisheries and there are many examples around the world where there are traditional access control systems in place, with multiple systems in Indonesia alone (Kumar 2010). Even recreational and sport fisheries have similar problems and solutions, such as heavy restrictions on access to salmon streams in Scotland. In Asia there is little, if any, room for expansion of participation in fisheries and shifting effort from one sector or area to another seems, at best, unwise. This would particularly be the case where effort was being shifted into sectors where there is little potential to monitor and control catches. Assumptions that small scale fisheries have no impact are not supported by research, unless catches are minimal. Gill nets, for example, have well non bycatch issues involving species-at-risk such as marine turtles and marine mammals.

The lessons learned from countries that have sustainable trawl fisheries point clearly to the need to keep the number of vessels and their fishing power (numbers and types of gears) at a level that would produce catches lower than the Maximum Sustainable Yield.

6.1.5 Some big and challenging questions

Fishing, like any other human activity, alters the environment in myriad, often subtle ways. Even a well-managed and sustainable fishery has impacts on the species of interest and such impacts are commonly deliberate. For example, fishing alters the structure of a fish population to favour the younger, faster growing components which produce more fish to use. Exploitation is commonly selectively focused on some species and not others which can create distortions in the structure of marine communities.

Our review has covered the phenomenon known as ‘predator release’ whereby the overfishing of higher trophic level species removed the predation pressure on lower trophic levels, resulting in larger numbers of fish. There are some obvious benefits to this from a food security and employment perspective as more fish are available for human use, which in populous coastal areas is an obviously desirable outcome. However, this phenomenon has not been driven by clear objectives not subject to effective management controls and is clearly negative from an ecosystem health perspective. As discussed by some authors this process has been the result of an uncontrolled experiment that has the potential to result in widespread ecosystem disruption.

Another concept which challenges the way that many believe fisheries should be managed is that of ‘balanced harvest’ which suggests that greater yields from ecosystems would be available if fishing mortality were set at a level commensurate with species requirements (Garcia et al. 2012). Modelling of this approach suggests that ecosystem stability is more assured than current selective fishing approaches. However, the challenge is managing the various fishing metiers in a way that achieves the balancing. Further investigation of this concept may reveal why the current unselective approach in Asia has not resulted in the ecosystem collapses predicted by some scientists.

Ecosystem-based management (EBM) which considers biodiversity is an environmental management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation. The rich set of international agreements of relevance to EBM contains a large number of principles and conceptual objectives which provide a fundamental guidance and a significant challenge for its implementation.

The available international instruments also provide the institutional foundations for EBM. The FAO Code of Conduct for Responsible Fisheries is particularly important in this respect and contains provisions for practically all aspects of the approach. One major difficulty in defining EBM lies precisely in turning the available concepts and principles into operational objectives from which an EBM management plan would more easily be developed (e.g. Garcia et al., 2003; Pikitch et al., 2004).

The Convention on Biodiversity and the Aichi Targets are also relevant here and have yet to be seriously considered in the context of the multi-species fisheries in Asia, despite various national commitments to these instruments.

Due to growing concerns that that aquaculture is contributing to the over-exploitation of fishing stocks for reduction purposes (e.g. forage/feed fish) the market for food derived from aquaculture is increasingly demanding that the marine ingredients (most notably, fishmeal and fish oil) used in farm feeds, come from responsible sources and is traceable back to the originating fishery. The fisheries in question must be able to demonstrate they are responsibly managed. The most widely accepted scheme used to demonstrate responsible marine ingredients, is the independently governed IFFO Responsible Supply standard (https://enaca.org/?id=913 – 8 March 2017). Only very limited sources meet the IFFO RS standard in Asia. Part of the problem stems from the nature of Asian fisheries, many of which are multi-species fisheries for which there are only limited amounts of data available. Another aspect is the lack of management or effective controls.

As in the case of the salmon mariculture industry, it is believed that dry compound pelleted or other feed types (not dependent on wild fish) will slowly replace the heavy dependence on wild captured fish for feed but this will be heavily driven by economic factors, such as fuel and feed fish prices (Tacon and Metian 2009), which may not kick in strongly enough to prevent major negative environmental impacts, such as overfishing. Other factors that could prompt the transfer at least to dry pellet feed (away from wet feed, although dry feed also includes wild fish) are biosecurity and diseaese risks of feeding unpasteurized forage fish to cultured fish, increased need for inexpensive lower value fish for direct human use and competition from other sectors for fish feed products (eg. pet food and bait for fishing) (Edwards et al., 2004; Tacon and Metian 2009). A growing consumer interest in sustainable sourcing is also being applied to the sourcing of feed which may also help to drive the transfer agenda. This situation calls for the management of wild feed sourcing for sustainability independently of the trends that will be driven by economic and other factors. It also calls for a wider consideration regarding what we are culturing and the need to consider a focus on lower trophic level species and less intensive approaches.

6.1.6 Fishery managers need to manage

Irrespective of what exploitation strategy is adopted (selective fishing, predation release, balanced harvest) or how much data are collected, the agencies charged with managing the fisheries need to move faster to put in place the controls needed for long term sustainability. For the past few decades it has been accepted practice to simply find new fishery resources when existing ones become overfished. This has created a pattern of serial depletion both in geographic terms and species terms and is no longer an acceptable or viable approach, certainly in the medium to long term.

Tere is a growing realisation that past practices have not delivered the desired, long-term benefits to rural communities, including flow-on effects into the wider community. Malaysia, Thailand and Vietnam have zoning systems to allocate gear types to particular areas but in the absence of proper effort controls and enforcement they have largely failed to deliver the sought after allocation of catches to targeted user groups (e.g. artisanal inshore and industrial offshore). Fishery managers have been either unwilling or unable to convince fishermen and politicians that resources are finite.

Management requires bringing stakeholders into the management process to ensure that there is acceptance and commitment to both the process and the outcomes. ASEAN governments have committed themselves to adopting the principles of comanagement as this has been deemed to be the best way of engaging stakeholders in helping make the tough decisions that will lead to an end to overfishing and rebuilding of stocks. Whilst it is true that cutbacks will be to the detriment of some users in the short term the experience to date has been that simply shifting effort around has not solved the underlying issues into the long term.

All the countries we have investigated have international commitments to managing their fisheries in a responsible way, national policies with commitments to sustainable use and have the legislative tools in place to regulate access and allocate catches, at least on paper. Thailand has fishery management plans in place which have precautionary targets in place (cap catches at 90% of multispecies MSY) and a series of time bound actions aimed at controlling IUU fishing and bringing the number of vessels permitted to fish down to a level which should help rebuild fish stocks. Vietnam has some, province based plans, which are also driven by clear objectives, but there is no national plan for those fisheries operating outside of provincial waters. Whilst China has a national commitment to cutting catches there are no fishery level management plans in place. Now is the time to put existing measures fully into practice, both national and in relation to international commitments, and to seek ways to ensure the health of the marine ecosystem of the ECS and SCS into the long term.

6.1.7 Recommendations for future steps, and data gaps

Seven key recommendations and data gaps emerge from our overview of the history and current understanding of the low value/trash fish sector of trawl fisheries in the SCS and ECS regions, our field studies and review of relevant literature. A key message is that without significant reduction in fishing effort most other measures will be very difficult to achieve.

Objective setting: Progress with fishery management planning and resource use keeping social, economic and biological considerations in mind requires clear objective setting at the national/regional level. Priorities for management could be economic, food security or livelihoods. Since all cannot be simultanesously optimized, decisions are needed to frame direction and identify key societal goals consistent with what the natural resources can sustain. Decisions regarding national priorities are also important for determining the appropriate management models to apply and identifying the data needed.

Data collection: There is a need for data collection on the species, volumes, sizes, catch locations and catch rates by major gear types of the catch component that goes to non direct food use. A better understanding of the economic value and destinations (i.e. utilization) of catches would greatly assist objective setting and management planning, while knowledge of catch origins will become increasingly important for traceability and seafood safety concerns. Data need to be collected in a standardized and comprehensive way as part of long-term monitoring programmes.

Effective management: It is clear that many of the trawl fisheries are seriously overfished in the region and in need of effective effort reduction and other management measures. In addition to the clear need for fishing effort reduction, other appropriate management can include controls on mesh size, spatial controls to protect spawning and nursery areas or temporal and spatial measures applied to limit certain types of catches.

While there are already many management measures on paper in the region, it appears that few are effective and hence much more focus and effort is needed on implementation. In addition, a major move that is needed, as in other fisheries, is the removal of subsidies that are facilitating overfishing.

Illegal, unmonitored and unregulated fishing: Although not covered much in this report is is clear that there is illegal fishing (for example mesh sizes that are too small, slavery on Thai vessels, Chinese trawlers in Hong Kong waters to name just a few examples) and that much of the trawl fishing in several countries in the region are largely unmonitored and unregulated. With much improved CCTV and georeferencing capabilities there is much scope for on-board monitoring of vessels and their tracking but requiring CCTV and VMS for example to be on all vessels of significant size. These technologies are no longer prohibitively expensive and are being increasingly applied elsewhere.

Alternatives to using wild fish as feed: There is clearly an urgent need to consider very carefully the best and most efficient uses of limited wild fish, and to a lesser extent invertebrates, in the supply of high quality protein to people. For example, research needs to be hastened to find non wild capture sources for feed, while culture species could be better selected to be those that require less wild feed (i.e. lower trophic level species). Moreover, if inexpensive food is needed as part of food security concerns then more fish should be directed towards direct human food uses and away from indirect uses, such as fish feed and fishmeal with their relatively low energy conversion rates.

Gear development to address management goals and reduce unwanted catch: Concerns over discards and unwanted bycatch have been addressed differently across the globe with the West (broadly) seeking to reduce unwanted bycatch (whether for reasons of conservation or to avoid sublegal size catches), when possible, and the East (broadly) seeking to find ways to use the bycatch. There is plenty of scope for gear modification to increase selectivity and avoid unwanted catch although this is unlikely to be applied if the focus is to use rather than to avoid bycatch.

International commitments, commitments and considerations: Into the new Millenium there has been a growing number of agreements, accords and perspectives (from the Convention on Biological Diversity to the Aichi targets to the application of CITES to commercial marine species, etc.) relevant to the use and stewardship of renewable marine resources. These increasingly recognize the growing threats some face and the long-term implications of these threats for humans and other species. Among other, these threats range from considerations of biodiversity and its relationship to food security and equity, conservation risks to megafauna and to highly valued but naturally vulnerable commercial species and biosecurity considerations. In turn, these issues are resulting in calls for certification of seafood (including sources of aquaculture feed), and improved traceability and accountability in seafood sourcing. With seafood the most extensively traded food at the international level and seafood processing and exports an important part of economies, much greater attention will be needed regarding the provenance, treatment, mode of production and efficiencies around seafood production than in the past.

7. Acknowledgements

We are extremely grateful to Jae Park, Vu Viet Ha, Hoang Ngoc Son, Kim Thanh Nguyen, Trinh Nhan,Wei Zhou, Liu Min, Elvis Wong Wenbo Zhang, Rachel Wong and Bruce Leung for assistance in preparing this report, data sharing and/or field work. Calton Law took the photos except as indicated. We acknowledge funding from RS Group, Swire Charitable Trust, ADM Capital Foundation. This report represents a contribution towards a global Situation Analysis on marine bycatch that was initiated by the IUCN Species Survival Commission Marine Conservation Sub-Committee, under the chairmanship of Yvonne Sadovy and Claudio Campagna.

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