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A path to a sustainable trawl fishery in Southeast Asia

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Abstract

Trawl fishing constitutes an important part of the marine fisheries sector in Southeast Asia. It provides livelihoods and food for millions of people in coastal communities as well as feed for the region's growing aquaculture sector. Trawl fisheries suffer from a multitude of problems, including overcapacity, excessive fishing effort, poor profitability and inadequate governance. The historical decline in catch per unit of effort, increasing proportion of low-value fish in trawl catches, widespread illegal fishing, and user conflicts reflect the weak management of these fisheries. Various measures implemented in the region have been insufficient to achieve sustainable outcomes. There has been little incentive for fishers to satisfactorily comply with the regulations. To understand better what kind of approaches would be effective and workable, the specific characteristics of SE Asian trawl fisheries are described and the fundamental barriers that must be addressed to improve sustainability and social benefits are identified. Meeting these challenges needs consideration of the socio-economic insecurity and the lack of alternative livelihoods as well as the complex ecological, cultural and institutional characteristics in the region. Simple, robust, equitable and easily enforced management measures are likely to work best in such a challenging environment. Properly implemented co-management systems would help to create incentives for individuals to cooperate. Trust building, participatory approaches, strong leadership and capacity building are important components to move SE Asian fisheries towards sustainability targets.

Keywords: trawling, management, barriers, solutions, incentives, leadership

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49 **1. Introduction**

50 The production of marine capture fisheries in Southeast Asia has continued to increase during the last
51 five decades, although recently at a slower rate than in 1960s-1990s (FAO 2018). Currently, six SE Asian
52 countries (Indonesia, Malaysia, Myanmar, Philippines, Thailand and Vietnam) contribute c. 18% of the
53 world's reported marine fisheries landings (FAO 2018). A large proportion of the increase in the fishery
54 production in the region has been attributed to the expansion of trawl fishing (Butcher 2004; Funge-
55 Smith et al. 2012). Trawling began to expand in the mid-1960s and since then has played an important
56 role in the region's food supply and livelihoods and has provided much needed income and foreign-
57 exchange earnings (FAO 2014).

58
59 There is general agreement that a vast majority of nearshore demersal fisheries resources in the SE
60 Asian region are overexploited (Christensen 1998; Abu Talib et al. 2003; Silvestre et al. 2003; Sugiyama
61 et al. 2004; Pomeroy 2012; Khatib 2015). Since the early 1970s there has been a general declining trend
62 in the catch per unit effort (CPUE) particularly for the most valuable species in demersal trawl fishing
63 (Kongprom et al. 2003; Stobutzki et al. 2006a; DOF 2015; Anon. 2016a). Furthermore, species
64 composition in demersal trawl catches has changed over time with an increasing proportion of small-
65 sized low-value fish (Butcher 2004; Garces et al. 2006a; Stobutzki et al. 2006b; Siar et al. 2017),
66 reflecting changes in demersal fish communities. These declining indicators have fuelled arguments that
67 intensive trawling has had a detrimental effect on fisheries resources and marine ecosystems in the
68 region (Butcher 2004; Pomeroy et al. 2016). Nevertheless, coastal fisheries resources also are intensively
69 exploited by many other metiers, and hence contribute to over-exploitation (Butcher 2004).

70
71 The profitability of trawl fishing has declined over time due to decreasing catches of valuable species
72 and increasing costs of fishing (Ahmed et al. 2007; FAO 2014; Siar et al. 2017). The trawl-fishing sector
73 has attempted to compensate for the reduction of revenues by increasingly targeting large volumes of
74 small-sized low-value species, known in SE Asia as "trash fish" (Funge-Smith et al. 2005; Nguyen 2017).
75 Low-value fish are used mainly as the base ingredient for feed in the growing aquaculture sector, either
76 directly, or through reduction to fish meal and oil. These fish also provide a source of cheap food for
77 domestic markets and are important for the poorest people (Funge-Smith et al. 2012). Low-value fish
78 have become an important, if not crucial, part of income and revenues in demersal trawling.
79 Development of new seafood products, such as surimi, has created additional demand for the fish raw
80 materials although in surimi production the quality requirements of fish are higher than in the feed
81 production.

82
83 The rapidly increasing demand for food and aquaculture feed in SE Asia has placed considerable
84 pressure on the region's coastal fisheries resources. Some progress has been made recently in the
85 management of the fisheries in the region, but resources are still largely exploited without effective
86 limits on the amount of fishing that takes place (Pomeroy 2012; DOF 2015; Derrick et al. 2017). To date,
87 attempts at regulating and controlling coastal fishing have been ineffective and volatile. Governments
88 have insufficient enforcement and surveillance capacity, and often there is a lack of consensus among
89 key stakeholders about which management actions would be effective. Short-term employment and
90 livelihood-maintenance strategies have a dominant influence. Weak stakeholder participation and
91 serious user conflicts characterize many of these fisheries (Salayo et al. 2006; Pomeroy 2012).
92 Furthermore, across the SE Asian region, large numbers of fishermen have resorted to illegal practices
93 to compensate for reduced catches, which in turn has further reduced the size of already dwindling
94 populations of the most valuable demersal species (FAO 2007). There is an urgent need to develop and
95 implement strategies that will help to ensure long-term sustainable fishing in the region.

96
97 During the last three decades, several studies, initiatives and projects have explored the problems and
98 suggested management solutions for SE Asian fisheries (e.g. SEAFDEC 2003; Silvestre et al. 2003; FAO
99 2014). Some countries (e.g. Thailand and Malaysia) have developed fisheries management plans (Anon.

100 2015; Anon. 2016a; DOF 2015) and have implemented these to the best of their abilities. The resources
101 of central and local bodies, however, are highly inadequate for managing the fisheries they govern, and
102 sustainability is rarely promoted and enforced in any substantive way (Pomeroy et al. 2010, 2016; FAO
103 2007, 2014; Nguyen 2017). Nonetheless, without the actions taken so far, the current fisheries
104 management situation would likely be worse.

105
106 The present study deals with trawl fishing, which is the most important and most challenging type of
107 fishing to manage in SE Asia (Gillet 2008). There are relatively few reliable statistics of the characteristics
108 and volume of trawl fishing in SE Asia against which to assess the fishing pressure. There is little reliable
109 documentation of the current catches, effort, viability and other key indicators of the trawl fleets. This
110 study seeks to address these knowledge gaps and provide an information base of the status and
111 complexities in the SE Asian trawl fisheries to better understand the fundamental motives and barriers
112 that have to be addressed to improve trawl fisheries management and guide transition to more
113 effective management practices in the region. Information for this study has been collected from
114 various official and unofficial sources, primary and grey literature, as well as from stakeholder
115 consultations and other outputs of various projects that have been conducted in the region, such as the
116 FAO-GEF REBYC-II CTI project (<http://www.rebyc-cti.org/>) that was operational in 2011-2017 (Suuronen
117 et al. 2013; Anon. 2016b; Siar et al. 2017).

118
119 The study describes the critical barriers in SE Asian trawl fisheries and provides guidance on best
120 management practices. The focus is on the crucial question of how to make a positive change in the
121 management of these heavily exploited multispecies fisheries. The study considered six SE Asian
122 countries (Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Vietnam) where trawl fishing has a
123 significant role in the marine fisheries economy. With the potential exception of Malaysia, these
124 countries have scored poorly in complying with the FAO Code of Conduct for Responsible Fisheries
125 (Pitcher et al. 2009).

126 127 **2. Characteristics of trawl fisheries in SE Asia**

128 **2.1. Trawler fleets**

129
130 The trawling sector in SE Asia is diverse and covers a wide range of vessel sizes, from small-scale
131 outrigger canoes powered by 10-15 hp engines up to industrial-scale trawlers with up to 1700 hp
132 engines (Butcher 2004; Aye and Win 2013; Duto et al. 2013; Nuruddin and Isa 2013; Nguyen 2017). Most
133 of the older trawlers are relatively small, less than 10 Gross Tonnage (GT) and <150 hp, are typically
134 made of wood and are poorly equipped. These vessels have a limited range and fishing capacity. Over
135 time, however, there has been a trend towards bigger and better equipped trawlers with an average
136 length around 14-18 m, engine size of 150-400 hp, and tonnage of around 10-50 GT or more. A
137 substantial number of newer trawlers have a steel hull with engine size >400 hp. The fishing capacity of
138 the vessels has increased due to the introduction of bigger engines, more powerful winches and better
139 fishing gear designs, as well as wider use of electronic aids, navigation technologies and acoustic
140 instruments for gathering information on fish disposition on fishing grounds (Butcher 2004; Gillet 2008;
141 FAO 2014; Siar et al. 2017). Large vessels can fish in the deeper offshore waters and use larger gears,
142 and may therefore have a higher catch rate. Nonetheless, the larger size has not necessarily made the
143 trawlers economically more viable than the smaller trawlers (Siar et al. 2017).

144
145 Most of the trawlers in SE Asia are otter trawlers targeting demersal finfish and shrimp. In some
146 countries, such as Vietnam, pair trawling is common, and a proportion of these pair trawlers target small
147 pelagic species such as anchovy. The total average number of trawlers in the six countries during the
148 period 2010-2015 was estimated at 47 500 vessels (**Table 1**). The overall number of effective trawling
149 units, however, was about 40 000 because a portion of these trawlers conduct pair trawling (two-
150 trawlers per unit). Approximately 15 000 of these trawlers are small-scale (<5 GT).

151 The yearly number of active trawlers is highly variable in each SE Asian country and the official numbers
152 of trawlers reported in general are an underestimate (Nguyen and Thi 2010; Purwanto 2010; Teh and
153 Teh 2014; DOF 2015; Pauly and Budimartono 2015; Teh et al. 2015; Derrick et al. 2017; Jumnongsong
154 2017; Ramiscal et al. 2017; CEA 2018). Typically, a large proportion of the vessels are not registered or
155 do not have an official licence and in general do not appear in the official statistics. Moreover, vessels
156 are often converted to another type of fishing when legislative conditions change. It is also worth noting
157 that the number of vessels tells little of the overall fishing capacity of a fleet. The size and engine power
158 of the vessels is a key measure. For instance, a <14 m Thai trawler in the Gulf of Thailand in late 2000s
159 typically caught 10-30 kg/hour, whereas a medium size of trawler (14-18 m; Fig. 1) caught 40-100
160 kg/hour (Supongpan and Boonchuwong 2010). Annex 1 provides more information of the development
161 of trawler fleets in SE Asia.

162 **2.2. Trawl operation**

163
164 Apart from the Arafura Sea industrial fishery, demersal trawling in the region largely occurs in nearshore
165 coastal waters (frequently <30 nm from the coast) and has a marked overlap and interaction with
166 fisheries using other gears such as gillnets (Garces et al. 2006b; Pho 2007; Garces and Silvestre 2010). In
167 some SE Asian countries, such as Vietnam, there has been a tendency for trawling activities to occur
168 further offshore (Nguyen 2017).

169
170 Demersal trawlers in SE Asia operate at depths ranging between 10 m and 100 m but are often
171 restricted to a maximum depth of about 70 m or less because of poor technical capacity of vessels
172 (Butcher 2004; FAO 2014). Smaller trawlers are able to trawl only in very shallow waters, often 5-30 m,
173 where the number of species and the proportion of small-sized fish are usually higher than in deeper
174 waters (Butcher 2004; Pho 2007). Bottom trawls in SE Asia are towed mainly on muddy seabeds but also
175 on mixed mud, clay and sand bottoms, and occasionally also on more sensitive grounds such as seagrass
176 beds. There is little scientific information of the potential impacts on seabed habitats and biota caused
177 by bottom trawling in SE Asia but apparently trawling has had impacts, and especially on shallow water
178 sea grass beds (Kongprom et al. 2003; Noranarttragoon and Phoonsawat 2012; Khemakorn 2014).

179
180 Trawl tow-times are typically 2-4 hours but as CPUE has decreased over time, fishers have tended to use
181 longer tow durations of up to 8 hours (Siar et al. 2017). This trend is linked to an expanding capture of
182 low-value fish used for the preparation of feed in the aquaculture sector where quality demands are not
183 as strict as with the human food sector. It is common practice in many SE Asian countries that much of
184 the catch is landed in plastic bags packed with some ice. Only the most valuable part of the catch is
185 properly stored and cooled with ice. The spoilage of catch is common. Annex 2 provides more details of
186 trawl operations.

187 188 **2.3. Harvesting pattern and bycatch in trawl fishing**

189
190 Trawl codend mesh size (stretched full mesh) in SE Asia is typically only 15-35 mm, and usually
191 somewhat less in shrimp trawling than in mixed finfish-shrimp trawling. In essence, the trawl fishing in
192 SE Asia is non-selective, resulting in large volumes of juvenile fish, small-sized fish species and other
193 organisms in the catches, especially when trawlers operate in shallow waters (Funge-Smith et al. 2005;
194 Eayrs et al. 2007; Siar et al. 2017). Discarding is uncommon except for the Arafura Sea industrial shrimp
195 fishery (Perez Roda et al. 2019). Nonetheless, special "Juvenile and Trashfish Excluder Devices" (JTEDs)
196 are utilized in the Samar Sea in the Philippines by the larger trawlers in order to have cleaner shrimp
197 catches (Ramiscal et al. 2017). Furthermore, the capture of endangered, threatened or protected
198 species such as rays, sharks and sea turtles is a cause of concern in SE Asian trawl fisheries but few
199 management actions have been taken to mitigate these incidental catches (Gillet 2008; FAO 2014). In
200 the Arafura Sea industrial shrimp trawl fishery, the use of a Turtle Excluder Device (TED) has been
201 compulsory since 1982 but there is no evidence that they are properly implemented (Af-idati and Lee

202 2009). In Vietnam, the capture of sea turtles and marine mammals is rare and trawl fishers normally
203 release them alive at sea (Nguyen 2017).
204

205 **2.4. Trawl fishing effort**

206
207 Except for Malaysia and Thailand, there is little reliable information of the total fishing effort of trawl
208 fishing in SE Asian countries. With the available data, only very rough estimates can be made of the
209 overall effort. Typically, trawlers fish year-round with some brief breaks during the year for vessel
210 maintenance (Siar et al. 2017). Fishers tend to maximize the fishing time at sea. Some countries (such as
211 Malaysia and Myanmar) have closed seasons when trawlers are not allowed to operate. For medium-
212 size trawlers it is common practice to stay at sea for 2-4 days, whereas larger vessels may remain at sea
213 up to 10 days or more per trip. Anecdotal evidence suggests that vessels are staying at sea longer,
214 travelling further and fishing deeper waters because of diminishing catch rates (Gillet 2008; Nguyen
215 2017).
216

217 In Malaysia, trawl fishing effort is recorded by the Department of Fisheries as the total number of trawl
218 tows per year. In 2012 there were c. 5.8 million trawl tows (Annual Fisheries Statistics, Malaysia). If an
219 average trawl tow is three hours in duration, the total trawling effort was c. 17.4 million hours. Dividing
220 this by 6028 trawlers (see Table 1), the average yearly towing time per boat would have been 2887
221 hours in 2012. The annual number of towing hours will vary considerably between vessels and year.
222

223 In the Gulf of Thailand (in 2010), the total fishing effort of the c. 2860 active Thai demersal trawlers (or
224 demersal pair trawling units) was c. 10 million hours (Noranarttragoon 2014). Hence, the average towing
225 time per unit would have been c. 3500 hours. For comparison, in 1990 the overall nominal fishing effort
226 of Thai demersal trawlers in the Gulf of Thailand was assessed as 15.4 million hours with a fleet almost
227 three times larger than in 2010 (Ahmed et al. 2007). During the period 1990-2010, the overall trawling
228 effort in the Gulf of Thailand declined by 30% while the fleet size declined by 60%. This indicates that a
229 reduction of fleet size did not lead to a corresponding reduction in the overall fishing effort. There is no
230 effort information available for the Thai trawling fleet in the Andaman Sea (Indian Ocean); it represents
231 c. 30% of the whole Thai trawler fleet.
232

233 **2.5. Trawl landings**

234
235 Demersal trawling in SE Asia is a complex multi-species fishery. Approximately 300 species of teleosts,
236 elasmobranchs, crustaceans, molluscs, and echinoderms frequently contribute to the landings (Butcher
237 2004). The species composition of the catch depends on a wide variety of factors such as the location of
238 the trawling activity, time of the year, the design and rigging of the gear, towing speed, and seabed
239 depth and type. Although shrimp is important in terms of economic value, targeted shrimp trawling has
240 become less common than in the 1960s and 1970s. This is mainly because of the poor profitability of
241 shrimp fishing due to declining catch per unit of effort (CPUE) of shrimp catches and the growth of
242 shrimp aquaculture. In the targeted shrimp fishery, the proportion of shrimp is usually 10-15% of the
243 total catch (Siar et al. 2017) and is typical for many tropical shrimp fisheries (Gillet 2008).
244

245 Assessing the country-level trawl landings in the region is not an easy task. The available statistics are
246 often contradictory, unclear and difficult to interpret. Only Indonesia and Malaysia provide official
247 country-level trawl landings data. For the other countries, we must use the landings data reported to
248 the FAO. However, these data are not partitioned by gear type. Therefore, we applied country-level
249 knowledge of the share of the total marine landings taken by trawl gears (Aye and Win 2013; Duto et al.
250 2013; Nguyen and Thi 2010; FAO 2014; DOF 2015; Siar et al. 2017) to the total marine landings reported
251 to the FAO by these countries. We estimated that in 2010-2016 trawl fisheries in the six countries
252 landed yearly on average c. 3.6 million tonnes of fish, shellfish and squid, representing 23.4 % of all
253 marine landings for those countries (**Table 2**).

254 The contribution of trawl fishing to the total catch varies significantly among the countries. In Malaysia,
255 Thailand and Vietnam trawl fishing provided 37-45% of all marine landings whereas in the other three
256 countries it provided 10-20% of the marine landings. Due to inadequate data, it is generally not possible
257 to separate how much of the total trawl landings are from otter-board and pair trawling. Nonetheless, in
258 2007 in the Gulf of Thailand trawl fishery, otter-board trawling constituted 80% of the total trawl catch
259 with 20% associated with pair trawling (Supongpan and Boonchuwong 2010). The data do not allow
260 trawl catches to be split between demersal and pelagic species. Nonetheless, the share of small pelagic
261 species is likely to be high in Vietnam where the use of high-opening pair trawls is common.

262 Country-level catch statistics reported to the FAO indicate the landings by species groups, such as
263 shrimps. Although a part of tropical shrimp landings is from various types of gillnet fisheries, the major
264 portion of tropical shrimp is caught by trawl (Gillet 2008). The overall shrimp landings reported to FAO
265 likely give the best available estimate of their shrimp landings in trawl fisheries of the six countries
266 included in this study (**Table 2**). The average annual shrimp landings in 2010-2016 was 623 943 tonnes,
267 which was 17.4% of the total estimated annual trawl landings in the six countries of this study. These six
268 countries provided about 47% of the total world-wide tropical shrimp landings in 2010 – 2016.
269

270 It must be emphasized that the catch reporting systems in SE Asian countries has high uncertainty and
271 the catch statistics at best give only a rough indication of the actual catches. In many countries, the
272 vessels do not maintain regular and accurate log-books of their catches (e.g. Nguyen 2017). In a highly
273 multi-species fishery it is a major challenge for the skipper to accomplish a detailed species-specific
274 catch report. Port-sampling occurs in larger fishing harbours but catch quantity and composition are
275 usually only roughly estimated. A significant amount of landings are reported to FAO as “*marine fishes*
276 *not identified*” or “*miscellaneous fishes*”. Nonetheless, because shrimp is an important export product in
277 all SE Asian countries, shrimp catch statistics tend to be more accurate than the statistic of catches used
278 in domestic markets.
279

280 **2.6. Status of fisheries resources and trawl CPUE**

281
282 The status of fisheries resources in SE Asia is poorly known due to a lack of appropriate monitoring data
283 and stock assessments. Most studies are outdated, and available data are often unreliable indicators of
284 the current status. Species-specific CPUE data from fishery-independent trawl surveys are currently the
285 best available measure of the status of demersal fishery resources. In the Gulf of Thailand, the state of
286 demersal fishery resources has been monitored continuously since the early 1960s with trawl surveys
287 (Joompol 2010; Khemakorn 2014; DOF 2015). All major target fish groups show a decrease in abundance
288 and biomass. The average CPUE of the survey trawl was 100-300 kg/h in the 1960s and 50-100 kg in the
289 1970s. In 2010-2013 the average CPUE had dropped to 12-15 kg/h (DOF 2015). It is not clear how well
290 the yearly trawl surveys have been standardized and whether they have systematically included all the
291 small-sized low-value species that currently compose the major part of commercial trawl catches.
292 Furthermore, the codend mesh size in the survey trawl may have been larger than what is currently
293 used in the commercial trawls (see Stobutzki et al. 2006b), perhaps resulting in a negative bias for
294 smaller individuals or species.
295

296 There are arguments suggesting that the effective removal of larger and longer-lived predatory species
297 has allowed a higher biomass of small, shorter-lived, fast-recruiting and low-value species (Gillet 2008;
298 Pomeroy et al. 2016; Szuwalski et al. 2017). This apparently has contributed to the maintenance of trawl
299 catches in SE Asia at a level where intensive exploitation remains profitable. In fact, the trends in
300 commercial Thai trawl catch rates in the Gulf of Thailand do not show a dramatic decline (Ahmed et al.
301 2007; DOF 2015; Siar et al. 2017). It is important to take into account the significant increase in vessel
302 fishing power over the last decades. Current vessels produce a markedly higher CPUE than did vessels
303 two-three decades ago.
304

305 In Malaysia the number of trawlers increased rapidly in the 1970s and commercial catch rates declined
306 gradually thereafter (Nuruddin and Isa 2013; Teh and Teh 2014). On the east coast of the Malay
307 Peninsula, average catch rates of commercial trawlers fell from 520 kg/h to 160 kg/h between 1970 and
308 1981, while in the northern part of the Straits of Malacca, catch rates fell from 130 kg/h to 55 kg/h
309 during the same period (Nuruddin and Isa 2013). Teh and Teh (2014) estimated that average catch rates
310 for trawlers of c. 100 hp declined between the 1970s and late 1990s from 30-40 kg/h to 23 kg/h. For
311 larger trawlers they estimated the decline was from 200 kg/h to less than 100 kg/h. More recent data
312 are not available, but by using the overall number of trawling hours and the trawl catches estimated in
313 this study, we can roughly calculate that the average CPUE of trawlers in Malaysia in 2012 was c. 38
314 kg/h.

315
316 Studies undertaken by the Research Institute for Marine Fisheries (RIMF) indicate that in Vietnam there
317 has been a marked decline in commercial trawl catch rates during the last two decades (Nguyen and Thi
318 2010; Nguyen 2011; Nguyen 2017). In Myanmar, the average annual total catch per trawler fell from 300
319 tonnes in the 1970s to 90 tonnes in 2006-2007 (Aye and Win 2013).

320

321 **3. Key barriers and potential solutions**

322 Trawl fisheries in SE Asia are subject to management measures that typically include license regulations,
323 gear prohibitions, and spatial and time restrictions, but these measures have been insufficient to
324 achieve sustainable outcomes (Pomeroy 2012; FAO 2014; DOF 2015). There are few regulations that
325 limit the total fishing effort or the total trawl catch. Catch limits have been applied only in the Arafura
326 Sea industrial shrimp trawl fishery. Trawl fisheries in SE Asia suffer from a multitude of interlinked
327 problems, including overcapacity, excessive fishing effort, illegal fishing, and poor governance (Stobutzki
328 et al. 2006a; Ahmed et al. 2007; Pomeroy 2012; Carbonetti et al. 2014). The following sections provide
329 insights into the challenges that frame future potential solutions. **Table 3** summarizes the key barriers to
330 and guidance for improvements in the sustainable management of these fisheries.

331

332 **Fleet overcapacity**

333 Fleet overcapacity is one of the leading causes of overfishing in SE Asia (Stobutzki et al. 2006a; Pomeroy
334 et al. 2016). License restriction is the most common approach in the region to control the size of the
335 fleets. In Malaysia and Thailand, recently there has been progress in fleet reduction by restricting the
336 number of fishing licenses by area (Nuruddin and Isa 2013; Anon. 2015; DOF 2015). Nonetheless,
337 registration systems are incomplete, and many countries have experienced difficulties in preventing
338 new entries into their fisheries and (e.g. Ahmed et al. 2007). Furthermore, even if the size of the fleet
339 could be reduced, fish stocks would remain a common resource available to the remaining fishing
340 vessels, which could become incentivized to fish more. In addition, maintaining the fishing power within
341 target range would require a constant reduction of the fleet size because the technical capacity of
342 existing vessels improves continually. This is a major challenge in SE Asian countries.

343

344 Reduction of fleet size means that a proportion of fishers would need to find new fishing opportunities
345 or other livelihoods. In SE Asia, there are few realistic alternative livelihoods for fishers and vessel
346 owners who are excluded from a fishery. They often do not have the education and/or skills required to
347 enable them to participate in other livelihoods. Alternative livelihood activities may also be less
348 profitable than fishing. Hence, displaced fishers may continue fishing by illegal means. Alternative
349 livelihoods should be offered in the fields that give realistic opportunities for success and for which
350 (given training and support) fishers have the necessary skills. These fields could include fish processing
351 and trade, aquaculture, coastal tourism, habitat restoration, manufacturing of artificial reefs, and
352 monitoring services supporting fisheries management. Alternative livelihoods could also be
353 supplementary and allow some level of fishing for displaced fishers.

354

355 It is worth noting that there are no effective vessel buy-back programs in SE Asia, which is partly due to
356 their expense (Willmann et al. 2003), but also because buy-back programs would not be effective in an
357 open-access system. Notwithstanding the problems, an effective freezing of the number of trawlers and
358 stricter control in the construction of new trawlers in all SE Asian countries would be an important first
359 step in taking control of fleet sizes (see also McConnaughey et al. 2020).

360
361 **Excessive fishing effort**
362 **Trawl fisheries in SE Asia** suffer from excessive fishing effort suffer from excessive fishing effort, which is
363 closely linked to fleet overcapacity. Most countries in the region have various types of plans to reduce
364 effort. For instance, the Thai Fisheries Management Plan has an objective to reduce fishing effort by
365 40% for demersal species in the Gulf of Thailand (DOF 2015). The reduction of effort will be achieved by
366 allowing only a certain number of fishing days per month for each trawler. It remains to be seen how
367 this regulation will be enforced and what will be the outcome.

368
369 Establishing a system of “total allowable days at sea” could be an appropriate step in all SE Asian
370 countries, although fishing grounds close to ports may become more heavily exploited. It is important
371 that there are regulations in place that prevent the compression of trawling activity into coastal areas
372 where there is potentially greater overlap with habitats and species of conservation concern. In
373 addition, potentially irregular landings may pose problems for processors that require continuous supply
374 of product. The initial setting of appropriate number of allowed days at sea might be difficult but the
375 system would allow adaptive learning. The great benefit of days-at-sea management is that it is
376 relatively easy and robust to control. Vessels can be seen and recorded when they remain in port and
377 they can be monitored remotely using satellite monitoring devices (if available) when they are at sea.
378 The costs of keeping vessels tied-up for several days per month may not be feasible for all vessel owners
379 (unless the CPUE increases markedly). Hence, only the most efficient vessels may be able to maintain
380 adequate profitability and continue the fishing.

381
382 Effort-control schemes are vulnerable to technological creep (Eigaard et al. 2014) and expansion of
383 other fisheries on the fishing grounds while trawl fishing is reduced (McConnaughey et al. 2020). A
384 major challenge in SE Asia is also the extensive geographical area and large number of fishing harbors
385 spread over the entire coastline and thousands of islands. The number of officials and patrol boats to
386 control the fisheries is inadequate in the region. Enforcement would need a strong participation from
387 the fishing sector (self-enforcing). In addition, various types of fuel-subsidies in many SE Asian countries
388 have exacerbated the high levels of fishing effort and contribute to the persistence of inefficient
389 operations. These subsidy systems should be reformed or removed (Sumaila et al. 2016). Funds that
390 currently are utilized for fuel subsidies could be redirected into development of alternative livelihoods
391 and value-added fish processing, as well as to improvement of fisheries management.

392
393 **Poor profitability**
394 Poor profitability of trawl fishing is both caused by and contributing to excessive fishing effort. It is
395 caused largely by the poor status of demersal fisheries resources (low CPUE) and by the low value of
396 species making up the catches but is also due to the characteristically high operational cost of fishing
397 (e.g. DOF 2015; Eayrs et al. 2017). Fuel often comprises 60-75 % of the operational costs for trawl fishing
398 in SE Asia (Eayrs et al. 2017; Siar et al. 2017). The long-term solution to increase the profitability in SE
399 Asia would be to allow a recovery of fisheries resources and then exploit these stocks sustainably with
400 an optimal fleet size and effort level. Such an approach would increase the CPUE and the profitability for
401 those vessels that remain within the fishery and would reduce the amount of time spent at sea, thereby
402 minimising secondary ecosystem effects of fishing on the wider ecosystem. Nonetheless, when
403 profitability is poor and there is no social security system, fishers have few realistic possibilities to
404 comply with management schemes that would restrict their current fishing effort, catch and hence
405 income.

406

407 Increasing the value of the catch would increase the profitability, but could also attract more fishing
408 effort. At present, product quality is negatively affected by inadequate catch handling and storage
409 practices associated with trawlers in SE Asia. Especially the smaller trawlers routinely experience 20-40
410 % spoilage of catch because of a lack of proper cold storage (e.g. Siar et al. 2017), and hence a major
411 share of the catches is marketed as low value product for the feed and fish meal industry. Shorter tows,
412 shorter trips, and better catch handling and storage practices would help to improve quality and price,
413 and to reduce fuel costs. Intensive training, technology transfer, and investment would be crucial to
414 develop higher-value products from fisheries resources. Reducing the direct costs of fishing offers
415 further possibilities to increase the profitability. Cruising at slower speeds, ensuring that the hulls are
416 regularly cleaned, and using optimal gear design and rigging would all lead to substantial decreases in
417 fuel consumption and would increase profitability (Eayrs et al. 2017). Nonetheless, all attempts to
418 improve profitability must include measures to control overall fishing effort.

419 **Inadequate zoning**

421 Coastal zoning is a widely used measure in SE Asia to prevent conflicts between the trawling sector and
422 small-scale inshore fishers, and to reduce the ecosystem impact of trawl fishing. Nonetheless, zoning is
423 seldom established based on scientific criteria (Garces et al. 2006a; Garces and Silvestre 2010); the
424 distance to the shore is the most common criterion. Identification of coastal areas that are most
425 vulnerable to demersal trawl fisheries is a fundamental task in developing effective zoning system.
426 Furthermore, zones are often poorly enforced, and trawlers frequently enter shallow fishing grounds
427 allocated to small-scale fisheries (FAO 2014). Use of modern satellite-based vessel monitoring systems,
428 with a strict requirement to keep it turned on, and clear visual marking of vessels, would help to ensure
429 that trawlers do not enter closed areas. Furthermore, because smartphones are widespread among
430 fishers, some fisheries have been able to incorporate geofencing into the mobile app so that vessels are
431 automatically notified when they enter protected area or exclusive fishing zones (Fujita et al. 2018;
432 USAID Oceans 2020). These type of low-cost tracking technologies would be helpful in SE Asia where
433 fishers do not necessarily know when they enter a protected zone.

434
435 Closures established in high-CPUE areas are often strongly resisted by fishers. In many cases the only
436 way to keep trawlers out of such areas is the use of physical anti-trawling barriers placed on the seabed.
437 These barriers could act also as artificial reefs that contribute to the rebuilding of fishery stocks and
438 ecosystem services. In Malaysia, monitoring conducted in part by fishers has been crucial for the control
439 of illegal fishing in the trawl free zones.

440
441 A measure related to zoning, yet untested in SE Asia, is to establish specific “allocated trawling areas”
442 where only trawl fishing is allowed (FAO 2014). Such an approach acknowledges the importance of
443 fishing for local livelihoods, but also acts to encourage fishers to fish in grounds that are known to yield
444 the best catches and thereby discourages ‘prospecting’ that leads to an expansion of trawl footprint. It is
445 worth noting that in South Africa specific trawling areas in the hake fishery have been tested with
446 promising results (Norman and Japp 2019).

447 **Extensive illegal fishing**

449 There is strong competition for fisheries resources in SE Asia and the whole region suffers from extensive
450 illegal fishing. Illegal fishing occurs region-wide, with violators ranging from local small-scale fishermen to
451 large-scale trawlers (FAO 2007; Nuruddin and Isa 2013; DOF 2015). Most of the violations are due to the
452 encroachment of trawlers into nearshore fishing zone. Illegal activities cause serious problems for
453 managing fisheries and lead to significant conflicts with those fishers who are operating according to
454 regulations and report their catches. The motivation to abide by regulations dramatically decreases
455 among all fishers when illegal activities are common on the fishing grounds. Illegal fishing is largely a
456 consequence of overcapacity and ineffective surveillance, but it is also linked to the poverty, insecurity
457 and corruption in the region. Reducing illegal fishing requires strong management policies and effective
458 monitoring, control and surveillance, including VMS and unannounced inspections at sea. It also requires

459 capacity building and training, use of new surveillance approaches such as drone-technologies and other
460 new technologies (USAID Oceans 2020), and better collaboration. It may potentially require also the
461 refusal of the fish market to buy illegally caught fish and strengthening the role of ecolabelling. The
462 existing regional instruments and action plans to combat illegal fishing (e.g. FAO 2007) should be enforced,
463 and synergistic national and local action plans need to be developed.

464

465 **Poor harvesting pattern**

466 There have been demands in SE Asia to reduce the extensive capture of juvenile fish in trawl fishing
467 (FAO 2014; DOF 2015; Siar et al. 2017). Codend mesh size regulations have not been effectively
468 enforced in the region and attempts to increase mesh size have resulted in protests by trawl fishers
469 (Butcher 2004). The effective mesh size has remained small, often in the range of 15-25 mm. There is
470 little incentive for fishers to conduct selective fishing because markets are readily available for all fish
471 biomass. The fishing industry should adopt mesh sizes that would optimise the harvesting pattern,
472 allowing juvenile fish to grow. Because the growth rate of young fish in tropical waters is high, a better
473 size-composition in fish populations could be achieved relatively quickly given suitable effort controls.
474 Voluntary uptake of larger mesh size, however, is unlikely when there are no immediate financial
475 benefits. Therefore, the mesh size regulations should be effectively enforced. Unexpected at-sea
476 boarding's would constitute effective enforcement and would also help to reduce other types of illegal
477 fishing activities and modern slavery onboard trawlers. Nonetheless, the increase of codend mesh size
478 would likely not be enough to change the situation in highly multi-species fisheries. To reduce effectively
479 the capture of juvenile fish, multiple measures are needed, including the avoidance of areas of high
480 density of juveniles and shallow water nursery grounds (FAO 2005). An additional option is to develop
481 positive business drivers linked to high catch quality and value instead of poor-quality bulk landings. The
482 ultimate solution would be to reduce the demand for fish in aquaculture feed and fishmeal production
483 by developing and utilizing alternative sources of protein.

484

485 **Lack of trust and co-management**

486 One of the main concerns in SE Asia is the lack of confidence among fishers regarding the rationality,
487 consistency and functionality of fisheries regulations, and doubt over whether other fishers will abide by
488 regulations (Pomeroy et al. 2016). When there is no trust, there is little incentive for fishers to comply
489 with regulations. Compliance with the regulations is realized when fishers have confidence that the
490 change will bring them positive results within a reasonable timescale. This confidence is often missing in
491 SE Asia. Trust can be built only when the fishers are convinced that every actor in a fishery will follow
492 the rules. This requires fair distribution of costs and benefits, participation, leadership, transparent
493 communication, effective measures to eliminate illegal actions, and adequate incentives. Strengthening
494 the role of local fisher associations would be important to ensure better communication of shared
495 objectives.

496

497 Various types of co-management arrangements have been recognized as a potential solution in SE Asia
498 (Pomeroy 1995, 2012). A well-planned co-management plan can be empowering and practical for the
499 appropriate scale of operation. Effective arrangements involving joint development of management
500 measures by fishers, government, local communities and fish byers have emerged for instance in the
501 Philippines (Anon. 2016a; Ramiscal et al. 2017) but are not yet widely utilized in SE Asia. Regional pilot
502 programs should be implemented to demonstrate the usefulness of co-management arrangements in
503 trawl fisheries. Implementing effective co-management often requires considerable input from the
504 government, including training and capacity building to fishers' organizations (Pomeroy 2012; Ramiscal
505 et al. 2017). Once a necessary capacity is built, governments can play a supportive rather than a
506 directive or managerial role.

507

508 **Lack of user-rights**

509 Rights-based approaches are a commonly advocated solution for creating incentives for fishers to fish in
510 a sustainable manner (Charles 2002; Grafton et al. 2006; Hilborn 2007). These approaches attempt to

511 create a sense of ownership of fisheries resources. In SE Asia user-rights systems are not well tested.
512 One major obstacle is the large number of different types of fisheries and vessels targeting the same
513 resources. The highly multispecies nature of fisheries in the region further compounds the underlying
514 complexity (Alam et al. 2002; Squires et al. 2003). The fact that user-rights are generally assigned to
515 fishers based on their catch histories may cause substantial problems because historical catch and/or
516 sales data are often non-existent in SE Asian fisheries (Ahmed et al. 2007). Another issue is the high
517 proportion of nomadic fishers from other communities who would likely not be part of the same user-
518 rights system. This would complicate any application of user rights.

519
520 There is a need to develop and test user-right approaches that would be suitable to SE Asian conditions.
521 Group fishing rights and territorial use rights for fishing, known as TURFs, provide a defined group of
522 users with a clearly defined area and the group of users regulate themselves to promote a cooperative
523 behaviour (Gelcich et al. 2012). TURFs require a collective group understanding of the value of the rights
524 and the capability to co-manage the resources (Pomeroy 2012). The group must have the ability to limit
525 access (e.g. from entities outside the group), which may be a major problem in SE Asia. More experience
526 is needed to assess the feasibility of TURFs in SE Asia, and hence the experimental trial of TURFs would
527 be a sensible first step in this region.

528
529 **Lack of scientific knowledge**
530 Stock status is one of the critical parameters used in the implementation of management plans and
531 measures to assess the sustainability of fisheries and fisheries resources (Branch et al. 2011). In SE Asia
532 most fisheries and species are not covered by any form of assessment. This has severely impeded the
533 ability of coastal authorities to make informed decisions on sustainable and responsible fishing
534 practices. There is also a significant lack of science-based knowledge about the region's marine
535 ecosystems to inform policies that would lead to the establishment of sound models for integrated
536 coastal management. Further, scientific capacity in fisheries management is diminishing in many
537 countries of the region (FAO 2014), in contrast to the urgent need for an increase in scientific
538 monitoring of fisheries resources in the region (APFIC/FAO 2012). Fishers should be part of the
539 monitoring process and fisheries log-book systems should be strengthened through innovative new
540 technologies such as remote electronic monitoring and catch analysis (Suuronen and Gilman 2020;
541 USAID Oceans 2020). Nonetheless, it is important to acknowledge that the basic problems in fisheries do
542 not lie in adequate science; they lie in human needs and human behaviour (Cochrane 2008).

543
544 **Inadequate regulatory frameworks and lack of political will**
545 The centralized top-down approach in SE Asian fisheries management focuses largely on formulation of
546 regulations that aim to maintain employment and production, reduce conflicts between different fishing
547 sectors, and adapt to natural disasters. There is a general political reluctance in the region to make hard
548 management decisions that would jeopardize the day-to-day livelihood and income of fishing families.
549 Furthermore, institutional structures are often deficient and management actions are characterized by
550 lack of coherence, consistency and clarity. There is an unsustainable mismatch between declining stock
551 status and growing fishery production targets for many SE Asian countries. Improving the horizontal
552 collaboration among various policy makers, agencies and local managers is fundamental to improve this
553 situation.

554 555 **4. Discussion and conclusions**

556 A range of barriers that impact the development of sustainable trawl fishing in the region were
557 identified in this study. Many of these barriers occur simultaneously, often with complex interactions.
558 Some of them affect all fishing sectors while others are closely linked to the trawl fisheries alone, in all
559 cases with varying degrees of importance. So far, there have been few attempts in SE Asia to prioritize
560 and address the barriers holistically. Instead, problems are often dealt with one-by-one as they arise. No
561 single measure, however, can achieve the full spectrum of actions needed (see also McConnaughey et

562 al. 2020). A suitable package of integrated actions is required to improve sustainability and rebuild the
563 depleted fish populations. This process requires the involvement of the whole fishing sector and will
564 only be effective if there is a genuine desire by all key stakeholders to achieve the objectives.

565
566 Complicated and data-intensive management approaches (such as species-specific catch quotas) are
567 currently not attainable for SE Asian fisheries. Instead, management solutions need to be robust and
568 flexible, and suitable for the highly multispecies and multiuser context with poor fisheries data. Different
569 intensities of management are possible and encourage simpler approaches when capacity and
570 knowledge is insufficient (Cochrane et al. 2011). The key management actions in SE Asia are to (i) reduce
571 excessive fleet size and overall fishing effort by areas for instance by a system of total allowable days at
572 sea, (ii) establish and enforce effective coastal zoning and appropriate seasons closed to trawling, (iii)
573 eliminate the uncontrolled entry of new fishers and vessels into fishing grounds, and (iv) reduce the
574 capture of juvenile fish and post-harvest losses. The success of these actions depends on the ability of
575 the system to enforce them, and to obtain the acceptance and compliance of stakeholders.

576
577 There has been insufficient incentive for SE Asian trawl fishers to alter their practices and satisfactorily
578 comply with the regulations. More emphasis must be placed on their motivation and capacity for
579 cooperation (see also Grafton et al. 2006; Cochrane 2008; Gutiérrez et al. 2011; Eayrs and Pol 2018). The
580 current top-down management does not create motivation. There is a need for management systems
581 that would meet the conservation objectives with as little loss of economic benefit as possible. It is
582 important to acknowledge here that rational science-based arguments alone may have no marked
583 impacts (Pomeroy 2012; Eayrs et al. 2014; Eayrs and Pol 2018). Building faith in a better future achieved
584 by improved management is fundamentally important and should have a high priority.

585
586 Fishers, their associations, and other key stakeholders should play a markedly more active role in the
587 management and monitoring of the fisheries. Co-management approaches that allow for a high level of
588 community self-determination are increasingly seen as an appropriate pathway towards sustainability.
589 Properly implemented co-management systems would help to create incentives for individuals to
590 comply with rules (Gutiérrez et al. 2011; Allison et al. 2012). The Ecosystem Approach to Fisheries
591 Management (EAFM) provides a process that could be utilized to include stakeholders in the co-
592 management arrangements (Staples and Funge-Smith 2009; Pomeroy et al. 2010, 2015). At the same
593 time the access to fishery resources in SE Asia should be rationalized. A rights-based system that
594 allocates fishing rights to a larger community group should be developed and tested in the areas and
595 fisheries where the chances of success are reasonably good.

596
597 Regulatory frameworks should clearly specify the requirements, rights, and responsibilities placed on
598 users to meet the goals. Once the management system is developed and enforced, it is important to
599 keep the stakeholders informed about how the fishery is performing and whether it is achieving the
600 objectives that have been set and whether the management system requires adjustments. In SE Asia,
601 the challenge is to establish adequate indicators for the highly multispecies fisheries (FAO 2014;
602 Leadbitter, 2016). Landings data collection requires substantial improvements.

603
604 Furthermore, as long as illegal fishing is largely unchecked on the fishing grounds, there is little hope for
605 improved management and restored fish stocks (see also Pomeroy 2012). The current system with poor
606 fisheries surveillance effectively rewards illegal operators. License and surveillance systems need to be
607 improved significantly, and fleet sizes need to be matched to the available fish resources. Governments
608 need to invest more resources and training in the at-sea monitoring and the fishing sector should be
609 harnessed for the self-regulation. The applicability of new and robust electronic monitoring technologies
610 should be tested.

611
612 There is a growing public opinion in SE Asia that bottom trawling is a destructive fishing practice and
613 must be banned (e.g. Loh and Jaafar, 2015). Nonetheless, if properly managed, trawling can continue to

614 be a significant source of food and economic benefit for the region's coastal communities. There are
615 good examples of well-managed tropical trawl fishing from other regions such as the Northern Prawn
616 Fishery in Australia (Macfadyen et al. 2013). The elimination of trawling would dramatically reduce the
617 supply of fish in the domestic market in SE Asia and would also reduce the supply of raw material for
618 fishmeal plants and aquaculture feed plants with potentially serious socio-economic consequences.
619 Moreover, trawling is often the most practical way to economically catch shrimp and many other
620 demersal species in industrial quantities (Suuronen et al. 2012). Ultimately, none of the benefits are
621 realisable if trawl fishing in SE Asia does not become a collaborative and sustainable undertaking.

622
623 Clearly, SE Asian trawl fisheries are difficult and complex to manage. Nonetheless, complexity should not
624 be abused by any interest group to avoid responsibility (Cochrane 2000). The complexity can be braked
625 into tractable bundles and effective solutions developed for each component. The management system
626 in the region requires comprehensive multisectoral policy coordination and effective co-management
627 arrangements. Approaches should consider the complex cultural and institutional characteristics of the
628 region, and the capabilities of the relevant management authorities. Governments should take a long-
629 term view and invest in the capacity building and demonstrate the benefits of management actions and
630 feasibility of shoreside employment based on sustainable fishery production. Governments should
631 promote training, demonstration projects and application of new technology among their agencies for
632 conducting effective enforcement and control. Governments should ensure that key stakeholders have a
633 proper understanding of how, why and for whom the fishery is managed. Management actions should
634 be designed with input from key stakeholders. Any pathway toward sustainability must also cover the
635 human slavery issue in the region.

636
637 Lastly, the improvement in sustainable use of natural resources in general takes place in parallel with
638 development in other key societal aspects such as education and health care (Morgan and Staples 2006;
639 Cochrane 2008; Melnychuk et al. 2017). Hence, the process will take time and it is unrealistic to expect
640 quick changes. It is also important to acknowledge that management of trawl fishing in isolation will not
641 enable sustainable nearshore fisheries in the region; all key fisheries must be managed if conflict and
642 unintended consequences are to be avoided.

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652 653 **Data availability statement** 654

655 Data sharing is not applicable to this article as no new data were created in this study.
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658

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908 **Table 1.** Estimated number and size of trawlers in the selected six SE Asian countries.

| Country | Number of trawlers | Size of trawlers | Remarks / Source |
|--------------------|---|---|---|
| Indonesia | 570 (Arafura Sea industrial trawler) ca 13 000 (small-scale) | 440 fish trawlers; average 263 GT 130 shrimp trawlers; average 153 GT Most vessels are 2-5 GT | Licensed trawlers in 2014 (Directorate General of Capture Fisheries). The estimate is highly uncertain. Many of these vessels are operating with trawl-like gears because trawling has been banned. |
| Malaysia | 6 028 | 70 trawlers <5 GT 3999 trawlers 5-40 GT 1370 trawlers 40-70 GT 589 trawlers >70 GT | Licensed trawlers in 2012 (Malaysia Department of Fisheries) |
| Myanmar | 1240 | 685 trawlers <24 m (average 82 GT) 555 trawlers >24 m (average 131 GT) | Licensed trawlers in 2015 (Department of Fishery, Myanmar) |
| Philippines | 300-500 (medium-scale) >2000 (small-scale) | Trawlers 12-22 m in length with engine power of 80-300 hp (20-200 GT). Small-scale municipal trawlers (usually <3 GT, 5-12 m, 5-16 hp) | Based on the Bureau of Fisheries and Aquatic Resources (BFAR) fisheries statistics in 2015 and Ramiscal et al. (2017). Official statistics include trawlers that are registered. There is large uncertainty regarding the number of municipal small-scale trawlers and many of them are >3 GT. |
| Thailand | 4087 | 225 trawlers <5 GT 304 trawlers 5-10 GT 517 trawlers 10-20 GT 1945 trawlers 20-60 GT 1096 trawlers >60 GT | Official statistic (DOF 2015). Ca 70% of the trawlers (2800 vessels) operate in the Gulf of Thailand (GoT) and ca 30% in the Andaman Sea. About 20-25% (<1000) of Thai trawlers are pair trawlers. |
| Vietnam | 20 100 | 7750 trawlers <90 hp 2800 trawlers <250 hp 3950 trawlers <400 hp 5300 trawlers <800 hp 300 trawlers >800 hp | Based on official statistics of the Department of Capture Fisheries and Resources Protection in 2015. Depending on the source, 50-75% of all trawlers (10 000-15 000 vessels) in Vietnam are conducting pair trawling. |
| In total | ~ 47 500 | | Ca 40 000 effective trawling units when pair trawling units (c 15 000 vessels) are counted as one unit. C. 30% of the trawlers can be categorized as small-scale (< 5 GT) |

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Table 2. Average annual marine fisheries landings and estimated annual landings (tons) in trawl fishing in 2010-2016 in six SE Asian countries. Average annual shrimp landings in 2010-2016 reported to FAO are part of the estimated trawl fishing landings.

| | Indonesia | Malaysia | Myanmar | Philippines | Thailand | Vietnam | Total annual average |
|--|-----------|-----------|-----------|-------------|-----------|-----------|----------------------|
| Average yearly landings in 2010-2016 (FAO FishStat) | 6 144 840 | 1 477 638 | 1 133 093 | 2 224 240 | 1 698 879 | 2 630 198 | 15 308 834 |
| Estimated yearly landings by trawling in 2010-2016 | 675 000 | 665 000 | 225 486 | 224 648 | 630 284 | 1 159 914 | 3 589 332 |
| Estimated share (%) of total landings by trawl | 11.0 | 45.0 | 19.9 | 10.1 | 37.1 | 44.1 | 23.4 |
| Average yearly shrimp landings in 2010-2016 (tons) FAO FishStat | 255 123 | 112 404 | 27 284 | 36 137 | 42 828 | 149 986 | 623 943 |

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916 **Table 3.** Summary of key barriers and challenges, and potential actions to solve the multitude of
 917 problems related to the management of trawl fishing in SE Asia.

| Barrier | Challenges | Guidance |
|---------------------------------|--|---|
| Overcapacity | <ul style="list-style-type: none"> • High demand for fish • Common property resources • Inadequate capacity to control fleet size • Lack of alternative livelihoods • Buy-back programs not affordable | <ul style="list-style-type: none"> • Establish target capacity for each fleet • Set effective caps on fleet size and power • Strengthen vessel registration systems • Prevent new entrances with effective license system • Establish access rights when feasible • Create realistic alternative employment opportunities • Stimulate broad-based rural development |
| Excessive effort | <ul style="list-style-type: none"> • Weak control of overall effort • No catch restrictions (no quotas) • Fuel subsidies • Lack of incentives • Race to fish | <ul style="list-style-type: none"> • Establish total allowable number of fishing days • Establish annual seasonal closures (when feasible) • Limit effort shift into other fishing types • Create business drivers linked to sustainable practices • Reform or remove the use of fuel subsidies • Establish engine size and trawl headrope length caps |
| Poor profitability | <ul style="list-style-type: none"> • Low value of catch • High operational costs • Poor infrastructure • Lack of capital to modernise vessels and gears | <ul style="list-style-type: none"> • Rebuild fish stocks (higher CPUE) • Maximize fishing efficiency and minimize time at sea • Increase value of catch (improve quality and processing) • Reform fuel subsidies • Promote better harvesting practices and infrastructure |
| Inadequate zoning | <ul style="list-style-type: none"> • Competition for fisheries resources • Trawlers encroaching sensitive shallow-water nursery grounds • Skippers unaware of no-trawling zones • Weak monitoring and surveillance systems • Poor utilization of vessel monitoring technologies | <ul style="list-style-type: none"> • Identify vulnerable coastal areas (e.g. seagrass, corals) • Establish effective trawl-exclusion zones • Establish closures preferably in low-CPUE areas • Establish effective surveillance and control systems • VMS systems on vessels require activated • Set physical anti-trawling barriers in sensitive grounds • Use individual visual markings for all trawlers • Promote a fishers' volunteer watch/reporting schemes • Test allocated trawling areas |
| Extensive illegal fishing | <ul style="list-style-type: none"> • Large number of unlicensed vessels • Extensive lack of catch reporting • Lack of effective monitoring • Unclear legal frameworks • Low risk of getting caught and many loopholes • Inadequate control of international joint venture arrangements | <ul style="list-style-type: none"> • Implement local action plans to combat illegal fishing • Build local surveillance and enforcement capacity • Utilize VMS and other technologies • Establish compulsory catch reporting systems • Close open access system to the extent possible • Promote capacity building and training in inspection • Promote inter-agency cooperation and consultations • Implement penalties (forfeitures of gear and vessel) • Prevent the marketing of illegal fish |
| Poor harvesting pattern | <ul style="list-style-type: none"> • Large amounts of juveniles caught • Unlimited demand for fish biomass • Bycatch of endangered species • Serious conflicts with other fishing sectors • Sensitive habitats disturbed | <ul style="list-style-type: none"> • Improve trawl selectivity step wisely • Avoid areas of high density of juveniles and ETP species • Develop positive business drivers linked to improved fishing pattern (higher value of catch) • Improve enforcement and set consequences that are uniformly applied |
| Lack of trust and co-management | <ul style="list-style-type: none"> • Lack of cohesive collaboration, communication and participation • Centralized top-down approach • Conflicting goals and corruption • Poverty pressure and insecurity • No consensus on measures | <ul style="list-style-type: none"> • Strengthen local authorities and fishers' associations • Promote local leadership and co-management • Establish transparent and frequent communication among all key stakeholders • Promote frequent stakeholder consultations and participation in management planning |

Path to a sustainable trawl fishery in SE Asia

| | | |
|----------------------------------|--|--|
| | <ul style="list-style-type: none"> • Lack of leadership at local level • Complex cultural features • Knowledge gaps | <ul style="list-style-type: none"> • Build consensus and reduce knowledge gaps • Secure fairness of management measures • Ensure that all participants follow mutually agreed rules |
| Lack of user-rights | <ul style="list-style-type: none"> • Lack of ownership of resources • Lack of motivation and interest • Objectives and measures not understood by key actors | <ul style="list-style-type: none"> • Develop appropriate co-management arrangements • Develop group fishing rights and territorial use rights • Harness peer pressure to improve the compliance |
| Lack of scientific knowledge | <ul style="list-style-type: none"> • Status of stocks poorly known and often contested • Impacts of management measures not known • Declining scientific capacity and lack of financial resources | <ul style="list-style-type: none"> • Increase science-based information of status of stocks • Increase evidence-based information on the potential positive impact of fisheries management measures • Strengthen fisheries log-book systems • Build capacity and increase funding • Promote education and build resilience |
| Inadequate regulatory frameworks | <ul style="list-style-type: none"> • Political reluctance to make hard management decisions • Priorities on short-term goals • Poor capacity and coordination • Deficient legal and institutional structures, complexity of systems • Lack of continuity and priorities • Unrealistic production targets | <ul style="list-style-type: none"> • Build monitoring and enforcement capacity • Clarify the key objectives of regulations; keep them simple and workable • Design management actions with key stakeholders • Establish incentives for effective enforcement • Promote training, demonstrations and new technology • Improve the horizontal collaboration among various policy makers, agencies and managers |

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922 **Figure 1.** A typical medium-size Thai trawler (Photo: Petri Suuronen).

923 **Annex 1: Development of trawler fleets in SE Asia**

924 The number of trawlers in the SE Asian region increased steadily from early 1960s to early 2000s
 925 (Butcher 2004; Morgan and Staples 2006). After that the overall increase was modest and in some
 926 countries such as Thailand the numbers have decreased. The country-level data of trawling fleets,
 927 however, is highly uncertain. Various statistics and sources often show very different numbers. In some
 928 cases, the estimates are fraught with uncertainties of several orders of magnitude. The following
 929 paragraphs summarize the development of trawler fleets in six SE Asian countries included in this study.

930
 931 **Indonesia:** Trawl fishing expanded in Indonesia in 1970s and negative impacts on fisheries resources
 932 were widely reported with serious user conflicts (Morgan and Staples 2006). Consequently, in 1980 a
 933 ban on industrial trawling was implemented in waters surrounding Indonesia except the Arafura Sea
 934 where industrial trawling was still permitted. However, the ban was never fully effective (Chong et al.
 935 1987; Bailey 1997) and by 1990s there was an extensive resurgence of trawling, with many vessels
 936 operating illegally. By the late 1990s, the trawl ban had ceased to be effective (Butcher 2004; Morgan
 937 and Staples 2006; Purwanto 2010; Endryono 2017). The trawler fleet in Indonesia had a rapid growth in
 938 early 2000s. This was linked also to the opening of new fishing grounds (Anon. 2010). Due to the
 939 trawling ban many of the trawlers were not been registered as trawlers.

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 941 According to the official Indonesian Capture Fisheries Statistics (Ministry of Marine Affairs and Fisheries,
 942 Directorate General of Capture Fisheries) the total number of trawlers in Indonesia in 2008 was 19 558.
 943 Of these trawlers, 2745 were classified as double-rig shrimp trawlers, 4399 as stern shrimp trawlers and
 944 12 414 as finfish trawlers (Anon. 2010). Most of the larger trawlers operated in the Arafura Sea and
 945 Makassar Strait. Purwanto (2015) estimated that in 2011 there were 731 industrial shrimp trawlers
 946 (average 130 GT) in the Arafura Sea area with overall catch of 48 370 tons of shrimp. Only 267 of these
 947 vessels, however, had a valid licence and their overall catch was about 17 680 tons. Hence, most of the
 948 vessels were fishing illegally. Furthermore, in 2014 the trawler fleet in Indonesia had about 13 000
 949 smaller coastal trawlers operating trawls or trawl-like gears, and about 570 industrial trawlers that
 950 operated mainly in the Arafura Sea (official statistics). Endryono (2017) reported that 129 of the Arafura
 951 Sea industrial trawlers were shrimp trawlers while 440 vessels were demersal fishfish trawlers. Most of
 952 the shrimp trawlers were 60-200 GT and most of the finfish trawlers 100-300 GT. The length of the
 953 industrial trawlers was 35-45 m. In addition, in early 2010s there were about 22 400 vessels in Indonesia
 954 that operated various types of bottom seines such as the cantrang-seine which is much like a Danish
 955 seine (Duto et al. 2013). The bottom seine fishing expanded after Indonesia in 1980 enforced the first
 956 trawling ban for vessels >5 GT. The adoption of seine fishing was a way to circumvent the trawling ban.

957
 958 The Ministerial Regulation no. 2/2015 banned all types of fishing with trawls and seine nets in Indonesia
 959 effective January 1, 2017. This new ban resulted in gradual shrinkage especially of industrial shrimp
 960 trawling in Arafura Sea (Endryono 2017). This has had major socio-economic impacts since Arafura Sea
 961 industrial shrimp trawling has contributed c. 45% of all shrimp catches in Indonesia. It is worth noting
 962 that the IUU fishing conducted by foreign vessels has been almost completely phased out in Indonesia
 963 under the new policy. This was accomplished with a tight at-sea control of fisheries (Endryono 2017; CEA
 964 2018). The 2015 trawling ban has been the subject of intensive debate and has faced strong resistance
 965 by the trawl fishing sector. The implementation of the ban has been delayed in many coastal areas (CEA
 966 2018). It is currently unclear how much trawl and seine fishing there is along the coast of Indonesia.
 967 The government of Indonesia has encouraged small-scale trawlers to replace trawl and trawl-like gear
 968 with other fishing gear through the gear-replacement program run by the Ministry of Fisheries.

969 **Malaysia:** The number of trawlers in Malaysia increased rapidly in 1970-1980s (Nuruddin and Isa 2013).
 970 Depending on the source and the year, trawl fishing contributes 45-48% of the total marine landings in
 971 Malaysia (Malaysia Department of Fisheries; Nuruddin and Isa 2013). In 2007 the licensed trawler fleet
 972 in Malaysia included 6340 vessels, 6116 vessels in 2011, and 6028 vessels in 2012 (Malaysia Department

973 of Fisheries; Nuruddin and Isa 2013). The number of licensed trawlers is apparently slowly decreasing.
974 Most of the trawlers are 5-40 GT but the number of trawlers of 40-70 GT is substantial. Although
975 Malaysia has one of the best data collection and fisheries monitoring systems in SE Asia, not all trawlers
976 operating in the Malaysian waters are registered and licensed (Teh and Teh 2014).

977
978 **Myanmar:** Myanmar had in 2015 c. 1240 licensed trawlers (Department of Fishery, Myanmar). In 2013
979 there were in total c. 1100 licensed trawlers (Aye and Win 2013) which indicates that the fleet has been
980 growing. Almost 45% of these vessels were more than 24 m in length. The average size was 131 GT and
981 engine power 677 hp, reflecting a high fishing power. The trawlers less than 24 m, however, also have a
982 substantial fishing power with the average gross tonnage of 82 GT. Pair trawling is banned in Myanmar.

983
984 **Philippines:** The Philippines has a markedly smaller trawling sector than the other countries of this
985 study. Most trawlers are municipal (coastal waters) vessels (<12 m in length, <3 GT, 10-16 hp). Many of
986 these municipal trawlers, however, are not actually as small as the regulations require (< 3 GT). Many of
987 them are markedly larger and are powered by 80-130 hp engines, and hence should be categorized as
988 small-scale commercial trawlers or large municipal trawlers (Ramiscal et al. 2017). The total number of
989 municipal trawlers is poorly known but obviously there are more than 2000 active vessels in the
990 Philippines (Ramiscal et al. 2017). Municipal trawlers are targeting mainly shrimp in the shallow water
991 coastal zone. In addition to the small-scale municipal trawlers, there is a commercial trawling fleet in the
992 Philippines. The commercial fleet expanded in the 1970s and early 1980s, and peaked in 1983 at 932 vessels
993 (BFAR Fisheries Statistics; Ramiscal et al. 2017). The number of commercial trawlers has decreased
994 during the last three decades due to the various trawling restrictions and increase of operation costs
995 (Armada, 2004; Ramiscal et al. 2017). In 2015 there were 156 medium-scale (20-150 GT) and 338 small-
996 scale (3-20 GT) commercial (licensed and registered) trawlers in the Philippines (Bureau of Fisheries and
997 Aquatic Resources, Fishing Vessels Electronic Licensing System). There were no large-scale (>150 GT)
998 trawlers in the vessel register. It is noteworthy that while the number of commercial trawlers has
999 decreased, the number of Danish seiners has markedly increased in the Philippines. In 2007 there were
1000 672 vessels conducting Danish seining (Ramiscal et al. 2017).

1001
1002 **Thailand:** In the early 1990s the total number of trawlers in Thailand peaked at around 13 000 vessels,
1003 of which c. 10 000 were demersal otter trawlers. Since then, the fleet has gradually been reduced
1004 (Supongpan and Boonchuwong 2010; Saikliang 2013; Noranarttragoon 2014; DOF 2015). In 2015, the
1005 total number of demersal trawlers was c. 4000 and of these vessels c. 1000 were conducting pair trawling
1006 (DOF 2015). The real number of trawlers is likely higher because not all trawlers in Thailand are
1007 registered and licensed (DOF 2015). Thailand is one of the few countries in SE Asia where the trawling
1008 fleet has been systematically reduced with the help of a strict license program. The significant
1009 reduction of trawler fleet size is reflected in the total trawl catch which reduced by almost one order of
1010 magnitude from mid-2000s to mid-2010s.

1011
1012 The major part (c. 2500 vessels) of demersal trawlers in Thailand are 10-18 m in length with engine size
1013 typically of around 150 – 300 hp and tonnage around 5-30 GT (Supongpan and Boonchuwong 2010;
1014 Eyars et al. 2017). An otter-board trawler in length class 14-18 m has an average tonnage of 27 GT.
1015 There is also a substantial number of trawlers in the 18-25 m length class (c. 500 vessels) with engine
1016 size of 150–500 hp and tonnage of around 20–80 GT (average 56 GT). Most pair trawlers are 18-25 m in
1017 length, have a tonnage of around 60 GT and engine size of 60-550 hp. There are also some larger otter-
1018 board and pair trawlers (25-63 m, 60-300 GT, engine size up to 1700 hp) trawlers; these off-shore
1019 trawlers have mainly been used in the EEZs of the neighbouring countries through the bilateral
1020 arrangements. The Gulf of Thailand is the most important trawling area of Thailand and up to 85% of
1021 Thai trawl catches are taken there (Supongpan and Boonchuwong 2010). There are about 100 beam
1022 trawlers in Thailand; their share of the trawl catch is 0.1%.

1023

1024 **Vietnam:** The size of the trawler fleet in Vietnam is the largest of all the six countries included in this
1025 study. The overall number of trawlers in 2015-2016 was c. 20 200 vessels (Department of Capture
1026 Fishery) but the size of the active fleet has fluctuated during the recent years. In 2010 the total number
1027 of trawlers was c. 19 670 (Nguyen 2013) and in 2008 c. 24 090 (Nguyen and Thi 2010). A significant part
1028 of the trawl fleet in Vietnam is conducting pair trawling. According to Nguyen and Thi (2010) in 2008
1029 there were 16 426 otter-board trawlers and 7665 pair trawlers (i.e., 32% of the total) in Vietnam. There
1030 are two types of pair trawling fisheries; one is targeting mainly pelagic species such as anchovies and is
1031 conducted with large trawls while the other is targeting mainly demersal species. Pair trawls are
1032 typically dragged along the seabed. Pair trawling is considered more cost-effective than single-boat
1033 trawling; this is mainly because a pair trawling unit can operate a bigger trawl in deeper waters and at
1034 higher speed than a single boat otter board trawler. Moreover, no energy is needed for dragging the
1035 trawl doors along the seabed. Shrimp/otter board trawlers have engine size of 20-400 hp and pair
1036 trawlers 90-800 hp. Most trawlers <90 hp target shrimp whereas trawlers >90 hp target finfish, squid
1037 and others (Nguyen 2013).

1038

1039 **Push-net fishing**

1040

1041 It is noteworthy that during the expansion of trawl fishing, a motorized push-net fishery also developed
1042 in many SE Asian countries and especially in Thailand (Silvestre et al. 1987; Nagalaksana 1987; DOF,
1043 2015) and in some regions in the Philippines. The gear is pushed by a boat over the bottom in shallow
1044 waters, especially to catch shrimp. The net is fixed on crossed poles to keep it open. To ensure that the
1045 poles glide smoothly over the bottom, they are fitted with runners. The poles of small push-net boats
1046 are 6 - 15 m long but large push-netters use poles up to 44 m. A census done in 1995 in Thailand
1047 counted about 4000 push-net boats (Butcher 2004). The census made in 2015 counted about 1500
1048 push-netters (DOF 2015). Most (82%) of these boats were relatively small (<10 GT) but there were also
1049 some boats larger than 60 GT. Hence, a significant number of push-netters are still operating in many
1050 areas in Thailand although the gear is banned.

1051

1052

1053

1054 **Annex 2: Trawl operation in SE Asia**

1055 Most trawling in SE Asia is single-net towing, i.e. the trawler tows only one trawl net. Multi-rig trawl
1056 arrangements (i.e., the trawler tows two or more trawl nets at the same time) are common in the
1057 Arafura Sea industrial shrimp fishery where double-rig trawls are used. Usually, no large bobbins or
1058 metal discs are attached to the ground-rope, but a chain and small rubber discs may be attached to it.
1059 Shrimp trawlers may use a tickler chain in front of the ground-rope. Uneven rocky bottoms are avoided
1060 because of high risk of gear damage.

1061
1062 The size of trawl gear depends on vessel size and power, fishing depth and target species. The headrope
1063 length of a typical bottom trawl towed by small- and medium-sized trawlers in SE Asia varies from 10 m
1064 to 25 m (Macfadyen et al. 2013; Eayrs et al. 2017; Siar et al. 2017). For the larger single-rig trawlers the
1065 headrope length is usually 25-35 m but can reach up to 50 m. In double-rig industrial trawlers in
1066 Indonesia the headrope length of the trawls is usually 15-26 m (Gillet 2008), i.e. the individual trawls are
1067 smaller than in corresponding single-rig trawling. Pair trawls are in general larger than single-net trawls
1068 and have a significantly larger vertical opening (Nguyen 2017). Although pair trawlers may also target
1069 small pelagic fish, the trawl is usually towed on the seabed. Along with the trend of building larger
1070 trawlers there has been a tendency in SE Asia toward bigger trawls with increased headrope length and
1071 mouth opening (Gillet 2008; FAO 2014). In Malaysia the government has limited the length of the trawl
1072 headrope to a maximum of 40 m to prevent the growth of fishing pressure and to discourage the
1073 building of larger and more powerful trawlers. There are no studies that have assessed the effectiveness
1074 of this strategy.

1075
1076 The door spread (distance between trawl doors during towing) in single-net otter trawls is typically 30-
1077 60 m in small-scale trawling, 60-90 m in medium scale trawling, and up to 150 m or even more in larger
1078 scale trawling. The wing-ends of the trawl net are connected to trawl doors by sweeps (bridles). A
1079 common length of sweeps in an average Thai trawler is 10-20 m (Eayrs et al. 2017) but sweeps can be
1080 markedly longer in larger fish trawls. In shrimp trawling it is a common practice to have very short
1081 sweeps, often only a few meters. Pair trawlers do not use trawl doors.

1082
1083 Towing speed in targeted shrimp trawling is typically 2.0 – 2.5 knots and in mixed finfish-shrimp trawling
1084 2.5 – 3.5 knots. In shallow-water small-scale shrimp trawling the towing speed may be only c. 1.5 knots.
1085 Pair trawlers can maintain higher towing speed than otter-board trawlers and are capable of catching
1086 faster-swimming species.

1087