A socio-psychological approach for understanding and managing bycatch in small-scale fisheries

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Abstract

Fisheries bycatch is the greatest threat to migratory, long-lived marine animals. Addressing bycatch ultimately requires changing fisher behaviour, yet social and behavioural sciences are rarely applied to bycatch mitigation, with an absence of theory-informed behaviour change interventions. Moreover, mitigating bycatch is particularly challenging in small-scale mixed-species fisheries, where perceptions of target and non-target vary widely, and all catches have economic or subsistence value. Such fisheries are ubiquitous throughout the world's oceans, and bycatch mitigation in these contexts necessitates a people-centered approach. We seek to address this gap, drawing on well-established theories from behavioural and social sciences. We first typify bycatch as a spectrum rather than a clearly delineated component of catch, where the position of a species on this spectrum depends on fishers' beliefs regarding the outcomes of bycatch-relevant behaviour. We then outline an approach to diagnose fishers' underlying beliefs about bycatch, using the Theory of Planned Behaviour (TPB): a widely-applied and empirically-tested theory for predicting and changing behaviour. Finally, we illustrate the approach using an empirical case study,

exploring fishers' beliefs regarding bycatch-relevant behaviour for three endangered elasmobranch species in a small-scale gill net fishery in Indonesia. In doing so show how the TPB can help to understand fishers' underlying beliefs regarding bycatch, and facilitators/inhibitors of bycatch mitigation, to inform behaviour change interventions. We emphasize the need to understand human dimensions of bycatch, especially in SSFs, where technical fixes alone will be insufficient to change behaviour. Rather, interdisciplinary approaches are needed to align fishers' needs with conservation objectives. Our bycatch spectrum and the TPB could be widely applied for disentangling drivers of bycatch in other SSFs and designing interventions which support more effective and socially-just marine conservation.

Key words: behaviour change, conservation, elasmobranchs, incentives, social norms, theory of planned behaviour

Introduction

Marine megafauna, such as sharks, turtles and cetaceans, are amongst the world's most threatened species (IUCN, 2021). The main threat is overfishing, sometimes via targeted fisheries, but most ubiquitously via incidental mortality (i.e. bycatch) (Davies et al., 2009; Lewison et al., 2004). This is common and particularly problematic in small-scale multi-species fisheries, where unselective gears are used to opportunistically catch a variety of fish (Shester & Micheli, 2011). In general, but in these types of fisheries in particular, bycatch is poorly defined, because perceptions of target and non-target vary (Davies et al., 2009). In practice, bycatch occurs on a spectrum (Figure 1), from undesirable incidental catch, which can be costly to fishers, to valuable retained secondary catch, which fishers may secondarily target. When seeking to manage bycatch in a particular context, it is important to diagnose where along this spectrum a given species falls, to design interventions that can effectively change bycatch-relevant behaviour. For example, if bycatch is undesirable, a low-cost technical fix may be feasible, however if bycatch mitigation has opportunity costs, incentives or compensation may be required to promote uptake (Hall, 1996; Matwal et al., 2014; Wosnick et al., 2020) (Figure 1).

Figure 1. A spectrum of bycatch, from undesirable incidental catch which has opportunity costs to useful secondary catch, which may have economic or subsistence value. Fishers' underlying beliefs, and appropriate interventions to change fisher behaviour, will be different at different places along the spectrum.

At its core, diagnosing and managing bycatch requires understanding and changing fisher behaviour, yet the use of behavioural sciences to inform marine governance and policy remains limited (Andrews et al., 2021; Campbell & Cornwell, 2008). A people-centred approach to bycatch mitigation is particularly important in SSFs, where almost all catches contribute to fishers' overall livelihood strategies, such that bycatch typically falls in the 'valuable secondary catch' category (Figure 1). This issue is ubiquitous throughout coastal areas – particularly in the Global South, where hotspots of marine biodiversity and dependency on marine resources overlap – and represents a cross-disciplinary challenge for biodiversity conservation, food security and livelihoods (Golden et al., 2016; Selig et al., 2014, 2018).

To contribute towards tackling this challenge, we outline how methods from social psychology – specifically, the Theory of Planned Behaviour (TPB) – can be applied to understanding and managing bycatch (Ajzen, 1991). We then illustrate the TPB's utility for eliciting information regarding fishers' beliefs about bycatch-relevant behaviour, with empirical data in a case study SSF: Lhok Rigaih in Aceh Province, Indonesia. This is an important case study because: 1) Indonesia is the world's largest shark fishing nation, where 99% of the fleet is small-scale, and is thus a global priority for reconciling trade-offs between biodiversity conservation, food security and livelihoods (Dent & Clarke, 2014; Dulvy et al., 2017; Halpern et al., 2008; Selig et al., 2018). 2) Lhok Rigaih is a multi-species multi-gear SSFs, in which Critically

61 Endangered species – such as hammerhead sharks (*Sphyrna* spp.) and wedgefish (*Rhynchobatus* spp.) – are
62 regularly caught as part of fishers overall livelihood strategies (Simeon et al., 2020). This is representative of
63 other SSFs in Indonesia, in the Global South more generally (Booth, Chaya, et al., 2021; Gupta et al., 2020;
64 Haque et al., 2021). Using this case study, we show how the results can be used to inform intervention
65 strategies to change bycatch-relevant behaviours. Finally, we outline broader implications and ways forward
66 for future applications, to design more effective and socially-just interventions for bycatch mitigation.

68 **A socio-psychological approach to bycatch**

69 Bycatch mitigation ultimately seeks to change human behaviour, by altering fishers' strategic and tactical
70 decisions to, for example, avoid hotspots, adopt bycatch-reducing technologies (BRTs), or release threatened
71 species (Campbell & Cornwell, 2008; Hall, 1996). Despite this, behavioural and social sciences are rarely
72 applied to understanding and managing bycatch (Andrews et al., 2021; Campbell & Cornwell, 2008). To
73 date, technologies and practices for mitigating bycatch (i.e. 'technical fixes') are relatively well documented
74 (e.g. BMIS, 2021), but less is known about how to encourage their adoption.

76 Interventions to change behaviour may be more effective if grounded in appropriate theory (Davis et al.,
77 2015). There are many theories of behaviour and behaviour change which can be applied to solving
78 environmental problems (Davis et al., 2015; Stern, 2018). We focus here on the TPB (Ajzen, 1991) since it is
79 one of the most widely-applied and empirically-tested theories of behaviour, including for predicting and
80 informing pro-environmental behaviour change (e.g., recycling), but with limited application to marine
81 conservation and fisheries management (Andrews et al., 2021; Davis et al., 2015; Nigbur et al., 2010; St John
82 et al., 2010; Tonglet et al., 2004).

84 According to the TPB a person's behaviour is determined primarily by intention (i.e., readiness to perform a
85 behaviour). Intention to perform a behaviour is driven by three factors: 1) attitude towards a behaviour, 2)
86 subjective norm and 3) perceived behavioural control (Ajzen, 1991). In turn, these factors are influenced by
87 an individual's beliefs about a behaviour: 1) behavioural beliefs, 2) normative beliefs and 3) control beliefs,
88 respectively (Ajzen, 1991) (Figure 2). Attitudes are based on the outcome expectations of performing a
89 behaviour (e.g., "I think it would be good if I catch a shark"), which are in turn influenced by individual's

90 positive or negative evaluation of the consequences of the behaviour (e.g., “catching a shark will provide food
 91 and income”). Subjective norms refer to perceptions of social pressure to behave in a certain way and can be
 92 divided into two types; descriptive - perceptions of peers’ behaviour, and injunctive - perceptions of whether
 93 peers approve or disprove of a behaviour (e.g., “People who are important to me would want me to catch a
 94 shark”). Social norms are influenced by normative beliefs about important peers approving or disapproving
 95 of a behaviour, and an individual’s motivation to comply with their peers’ views. Perceived behavioural
 96 control (PBC) relates to the ease or difficulty of performing a behaviour depending on the context (e.g., “I
 97 feel it is within my control whether or not I catch a shark”). PBC is influenced by control beliefs about the
 98 likelihood that facilitators (e.g., the season, available technology) or inhibitors (e.g., bad weather) might
 99 occur that help or hinder the likelihood of performing a behavior. As well as driving behavioural intentions
 100 PBC also directly influences behaviour (Figure 2) (Ajzen, 1991). In general, the more positive a person's
 101 behavioural, normative, and control beliefs, the greater their behavioural intention, and the higher the
 102 likelihood that they perform a behaviour, and previous studies have shown that they reliably predict other
 103 pro/anti-environmental and -social behaviours, such as recycling, smoking and healthy eating (Davis et al.,
 104 2015; Nigbur et al., 2010; Tonglet et al., 2004). Moreover, identifying and changing salient beliefs can
 105 influence intended and actual behaviours.

B

Figure 2. The theory of planned behaviour, with example beliefs relevant to bycatch. Panel A relates to catching species X while Panel B relates to avoiding or releasing species X. Green boxes represent positive beliefs towards the behaviour and orange boxes represent negative beliefs towards the behaviour. (adapted from St. John et al. 2010).

TPB is particularly appropriate for fisher behaviour, since it acknowledges that behaviour is multi-faceted, multi-levelled and multi-scaled (Andrews et al., 2021). That is, TPB allows for different types of outcome expectations with different levels of influence (e.g., behavioural beliefs, which depend on perceived external rewards at the individual-level; normative beliefs, which depend on social pressure at the societal-level; control beliefs relating to environment/context). Unpacking these influences on fisher behaviour is important, since different beliefs can act synergistically or antagonistically, and may align or be in conflict with conservation objectives. For example, outcome expectations which are extrinsically rewarding (e.g. food, income) can crowd in or crowd out those which are intrinsically rewarding (Cinner et al., 2021; Grillos et al., 2019). Similarly, different scales of influence can interact, such as conflicts and synergies between individual beliefs and social norms, or between formal laws and local customs (Bicchieri, 2017; Booth et al., 2020; Oyanedel et al., 2020). Bycatch mitigation in SSFs is also a challenge for equity and environmental justice. Coastal communities often experience the greatest opportunity costs of marine conservation, with a we need for a deeper understanding of the values and importance of marine megafauna from the perspectives of small-scale fishers (Balmford & Whitten, 2003; Booth, Squires, et al., 2021; Stevenson et al., 2013). TPB can help to meet this need by building a deeper understanding about the advantages/disadvantages of

bycatch and bycatch mitigation, and socio-economic barriers and facilitators thereof. Therefore, applying the TPB to bycatch can help to unpack fishers' salient beliefs about bycatch, and underlying socio-economic drivers. For example, if attitudes and norms towards catching threatened species are negative, but perceived behavioural control towards avoiding them is also negative, interventions which improve behavioural control (such as cost-effective BRTs) could be appropriate. Conversely, if attitudes and norms towards catching threatened species are positive, underlying socio-economic motivations may hinder uptake. In these situations, economic or social incentives may be required (Nyborg et al., 2016; Sykes et al., 2018; Wosnick et al., 2020). This information can help to 'diagnose' the typology of bycatch (Figure 1) for a given species and context, and inform the design of management interventions to target salient beliefs and change fisher behaviour.

Case study: using the TPB to understand bycatch-relevant behaviour in an SSF in Indonesia

Case Study background and methods

We illustrate application of the TPB for eliciting fishers' salient beliefs regarding bycatch-relevant behaviours in a coastal gill net fishery in Lhok Rigaih, Aceh Province, Indonesia. This is a pertinent case study for several reasons. Firstly, Indonesia is a global priority for aligning SSF management, marine conservation and human well-being (Golden et al., 2016; Selig et al., 2014, 2018). Secondly, the fishery context is representative of coastal SSFs in the tropics in terms of gears, habitat types and bycatch-affected species, therefore the methods and findings should be broadly applicable to other SSFs around the world (Gupta et al., 2020; Haque et al., 2021; Harry et al., 2011). Finally, the socio-cultural context in Aceh Province represents an interesting case for testing a socio-psychological approach, as it is home to a customary fisheries management institution called the *Panglima Laot*, which is responsible for maintaining security at sea and managing coastal resources (Quimby, 2015; Wilson & Linkie, 2012). It therefore represents a location where expectations regarding economic outcomes and social norms interact within the realm of fisheries management and conservation.

Within this site we conducted a belief elicitation study structured around the TPB which aimed to answer the following questions:

1. What are fishers' salient beliefs regarding three by-catch relevant behaviours: a) (by)catching and retaining, b) not catching/avoiding, and c) releasing endangered species?
2. Based on these beliefs, where does fisher behaviour sit along the spectrum of bycatch (Figure 1)?
3. What are the implications for designing of behaviour change interventions for bycatch mitigation?

For each by-catch relevant behaviour we conducted a comparative case study of three endangered elasmobranch species: hammerhead sharks (*Sphyrna* spp.), wedgefish (*Rhynchobatus* spp.) and whale sharks (*Rhincodon typus*), which represent conservation priorities, and contrasting case-types in terms of their ecology and socio-economic characteristics.

Site description

Aceh Jaya regency is on the south coast of Aceh Province, Indonesia. It is home to important marine habitats, with extensive mangroves, turtle nesting beaches, and shallow coastal waters with muddy substrate and coral reefs which provides nursery grounds for a range of endangered species (DKP Aceh, 2018). Much of Aceh Jaya's population adopt mixed subsistence livelihoods such that the coastal waters of Aceh Jaya also represent an important marine resource, characterised by small-scale multi-gear mixed-species fisheries which support food security and livelihoods (Yulianto et al., 2018).

In Aceh under the *Panglima Laot*, coastal management is primarily conducted at the '*Lhok*' level. *Lhok* essentially translates to bay, and is a spatial area encompassing a portion of the coast and associated marine habitat, which is the smallest unit of customary management in Aceh according to customary law (Qanun Aceh Nomor 9 Tahun 2008 Tentang Pembinaan Adat Dan Adat Istiadat, 2008). There are 8 registered Lhoks in Aceh Jaya, and Lhok Rigaih is home to the largest harbour and landing site in the regency. It serves six villages across two districts and approximately 200 full- and part-time fishers, while also being representative of the other Lhoks in Aceh Jaya in terms of fishery characteristics (i.e. gears uses, species caught and habitat) (Yulianto et al., 2018). There are three main gear types used in Lhok Rigaih – gill nets (*jaring*), longlines (*rawai*) and handlines (*pancing*), with available data indicating that bottom-set gill nets (*jaring tancap*) are by far the highest-risk gear in terms of bycatch of endangered species, accounting for roughly 80% of total hammerhead sharks and wedgefish bycatch (Simeon et al., 2020). Landed hammerheads are typically juveniles, and therefore represent limited economic value per individual, but are caught frequently and consumed locally (Simeon et al., 2020). In contrast, large wedgefish have high value in the

international fin trade (Hau et al., 2018). In contrast again, while whale sharks are anecdotally encountered by fishers, and can become entangled in gill nets, they are rarely caught and landed in Lhok Rigaih.

Study design and data collection

When applying the TPB, belief elicitation studies are conducted to understand salient beliefs among a target population, which can inform the design of behaviour change interventions by identifying which beliefs should be targeted (Ajzen, 1991, 2011). We used in-depth semi-structured interviews as our primary data collection method, to elicit fishers' salient beliefs, and gather additional qualitative and quantitative data on the socio-ecological system of the fishery (fishing practices, subjective well-being, social relations, and institutions) and individual demographic variables of the fishers (e.g., age, income, experience) (S1). We structured the interview questions following guidance from Ajzen 2013 (Ajzen, 2013b, 2013a). Specifically, we asked questions regarding beliefs about the likely consequences of each by-catch relevant behaviour (behavioural beliefs), normative expectations of others regarding the behaviours (normative beliefs), and the presence of factors that may facilitate or impede performance of the behaviours (control beliefs), where the behaviours examined were catching species X, not catching species X and releasing species X. For each belief we asked Likert-scale questions on a scale from 1 to 7, where 1 represented a strongly negative response, 4 represented a neutral response and 7 represented a strongly positive response, and responses were framed as varying degrees of good/bad, true/false or agree/disagree along this 7-point spectrum depending on if the question referred to advantages/disadvantages, approvers/disapprovers, facilitators/barriers (S1). Each Likert-scale question was then followed with a qualitative open-ended question, where fishers were asked to explain their answers and describe the relevant advantages/disadvantages, approvers/disapprovers, facilitators/barriers (S1).

In total we conducted 16 in-depth semi-structured interviews (14 with active *jaring tancap* fishers and two with active *jaring lobster* fishers who has previously used *jaring tancap*), complemented with an FGD with local marine managers, and informal discussions and direct observations at Lhok Rigaih harbour and a local coffee shop. Since this was a descriptive and exploratory study, we conducted opportunistic, snowball sampling, with no a-prior assumptions regarding sample sizes, and continued collecting data until saturation (Cohen & Crabtree, 2006; Newing et al., 2010). At the time of the study, eight *jaring tancap* boats were operating in Lhok Rigaih, which can employ up to 24 fishers, with each vessel taking 2-3 crew. As such, we

214 estimate our sample represented at least 58% of the active *jaring tancap* fishers. Our sample focused on vessel
215 captains (10 out of 16) and included the current *Panglima Laot* of Lhok Rigaih as key informants. The FGD
216 included eight local marine managers from the Aceh Jaya regency *Panglima Laot* and regency fisheries
217 agency.

218

219 Data were collected during February 2021, by the lead author (HB) with assistance from a translator (MI),
220 two trained research assistants (LR and RH) and a local enumerator to facilitate introductions to fishers
221 (KBN). This research was conducted under a foreign research permit for the lead author (No. Surat Izin:
222 407/ E5/E5.4/SIP/2019), with ethical review and approval from the University of Oxford Medical Sciences
223 Interdivisional Research Ethics Committee (MS IDREC) (ref. R66416/RE001).

224

225 *Analysis*

226 We conducted simple descriptive and thematic analysis of the results, with graphical figures prepared using
227 RStudio (RStudio Team, 2020).

228

229 **Case Study Results**

230 *Socio-ecological context*

231 Gill net fishers in Aceh Jaya are typically middle-aged (30 to 59 years) married men, with primary- or
232 middle-school level formal education and many years of fishing experience (average = 25). Every fisher
233 reported that they target ‘ikan *apa pun*’ / ‘ikan *apa saja*’ (any fish), reflecting the mixed-species nature of the
234 fishery, and that fishing covers their ‘*kehidupan sehari-hari*’ (daily needs or livelihood). Most fishers reported
235 positive or neutral subjective well-being, and expressed a strong sense of ocean stewardship (e.g., “*ada rezeki*
236 *di laut*” (there are gifts from God in the ocean)) and social connectedness (e.g., “*di laut semua saudara*” (at sea
237 we are all brothers)) (S2).

238

239 *Catching, avoiding and releasing endangered elasmobranchs: fishers’ beliefs, intentions, and behaviour*

240 *Beliefs*

241 Fishers reported strong positive behavioural and normative beliefs regarding catching wedgefish and
242 hammerheads (Figure 3), with neutral to negative beliefs regarding avoiding and releasing them (Figure 4).

243 In contrast, they held strong negative beliefs regarding catching whale sharks (Figure 3), and positive
 244 beliefs regarding avoiding and releasing them (Figure 4).
 245

246 Positive behavioural beliefs were strongest for catching wedgefish (mean score of 5.9/7 on Likert scale,
 247 Figure 3), with all fishers stating financial gain as an advantage e.g. *"If it's big it's great, I can get lots of money"*.
 248 Behavioural beliefs for catching hammerheads were also consistently positive, with food more commonly
 249 mentioned as an advantage (mean = 5.5/7, e.g., *"We can sell it or eat it"*). The term *"rezeki"* (gift from God)
 250 was also commonly used to describe these catches (Figure 3). Attitudes were reinforced by normative beliefs,
 251 with almost all fishers believing that most people catch wedgefish and hammerheads, and approve of their
 252 capture e.g., *"They are landed here every day"*, *"People approve... we eat it"* (Figure 3). Control beliefs for
 253 wedgefish and hammerheads were generally positive but less consistent, with fishers reporting stochasticity
 254 as a barrier, e.g., it depends on "luck" and/or "God's will" (Figure 3).
 255

256 Behavioural beliefs regarding not catching wedgefish and hammerheads were neutral-to-negative, with
 257 many stating *"tidak apa-apa"* (no problem) or *"Insh'Allah"* (if God wills). Control beliefs for avoidance were
 258 generally negative, with fishers stating *"they just come to the net"* (for wedgefish) or *"they are everywhere"* (for
 259 hammerheads), though some fishers revealed seasonal and spatial elements to bycatch, with catches of
 260 hammerhead sharks being particularly high during May to August. Behavioural beliefs regarding releasing
 261 wedgefish and hammerheads were also generally negative. Disadvantages included less income (e.g., *"it*
 262 *brings more money even though it's not the target"*) and *'mubazir'*. *Mubazir* literally translates as wasteful, but
 263 also has religious connotations, and implies that God will be displeased. However, some fishers reported
 264 advantages, e.g., *"if it's small and alive ... it can make more fish"*. Control beliefs regarding releasing wedgefish
 265 and hammerheads were heterogenous. For wedgefish, control beliefs were neutral-to-slightly positive, with
 266 reports that they are sometimes alive and typically *"stronger than hammerheads"*. For hammerheads, four
 267 fishers reported strong positive control beliefs and four reported strong negative control beliefs. Those that
 268 reported negatively stated that hammerheads are usually or always dead when the gear is brought up, while
 269 those that reported positively conditioned their answer with *"if it's small and alive"* (Figure 4).
 270

271 In contrast, all but one fisher (N = 15) consistently reported strong negative beliefs regarding catching
 272 whale sharks and strong positive beliefs regarding releasing them, which were backed up by statements

273 regarding customary beliefs and norms (Figure 3). E.g., fishers stated “*dia bawa rezeki*” or “*dia bawa ikan*
274 *kecil*” (she/he brings gifts from God or she brings the small fish), and reported that whale sharks cannot be
275 consumed or sold under government and customary regulations. All but one fisher reported positive control
276 beliefs regarding releasing whale sharks, stating that they are “*strong*”, “*calm*” and “*not dangerous*” so it’s easy
277 to release them (Figure 4). The only reported disadvantage was they sometimes have to cut their net,
278 though other fishers said this wasn’t necessary.

279

280 *Intentions*

281 For both wedgefish and hammerheads, there was a disconnect between beliefs and intentions. When fishers
282 were asked if they intend to catch these taxa, answers were inconsistent and neutral on average (for
283 wedgefish, mean score = 4.2/7, for hammerheads, mean score = 3.8/7). Some fishers stated that they wanted
284 them, others stated that it wasn’t their target (Figure 3). Intentions for releasing hammerheads and
285 wedgefish were consistent with beliefs and predominantly negative (Figure 4). For fishers who were neutral
286 (N = 4), they explained that if it was small and alive they would release it, but if it was big and/or already
287 dead then they would not. One fisher stated that if they were protected by the *Panglima Laot* he would be
288 willing to release them. For whale sharks, reported intentions to catch, avoid and release them were
289 consistent with beliefs; strongly negative for catching them and strongly positive for avoiding and releasing
290 (Figure 3, 4).

291

292 *Behaviour*

293 Most fishers reported having caught wedgefish or hammerheads in the past three months, and having not
294 released them, however three fishers reported releasing a small wedgefish and one fisher reported releasing
295 a small hammerhead. No fishers reported catching whale sharks (Figure 3, 4).

Figure 3. Summary of the positivity/negativity of fishers' beliefs regarding (A) catching and (B) avoiding wedgefish, hammerheads and whale sharks, where negative pertains to all responses that were 'bad', 'disagree' or 'false', while positive pertains to all responses that were 'good', 'agree' or 'true' (see S1 for details on question framing). The bars represent quantitative results from Likert-scale questions, while the quotes below each bar represent an illustrative qualitative explanation from one or more fisher.

Figure 4. Summary of the positivity/negativity fishers' beliefs regarding releasing wedgefish, hammerheads and whale sharks, where negative pertains to all responses that were 'bad', 'disagree' or 'false', while positive pertains to all responses that were 'good', 'agree' or 'true' (see S1 for details on question framing). The bars represent quantitative results from Likert-scale questions, while the quotes below each bar represent an illustrative qualitative explanation from one or more fisher.

Interpretation of results within the spectrum of bycatch

These results suggest that in Lhok Rigaih, (by)catch of wedgefish and hammerheads can be diagnosed as valuable secondary catch (Figure 5). In general, fishers believed that (by)catching and retaining hammerhead sharks and wedgefish has advantages for income and subsistence, and widespread social approval. Perceived behavioural control was relatively high, while accounting for intervening factors including the weather, the season and luck or 'God's will'. In contrast, avoiding and releasing hammerheads and wedgefish have disadvantages in terms of lost income, food and 'mubazir', and these behaviours are not widely accepted social norms. Control beliefs regarding avoiding and releasing were mixed, with intervening factors relating to catchability and survivability of hammerheads and shovelnose rays which were generally consistent with independent studies (Ellis et al., 2017; Wosnick et al., 2020).

On the other hand, catches of whale sharks can be diagnosed as undesirable incidental bycatch (Figure 5), with disadvantages of catching them including no economic value or market, and social disapproval because of their perceived role in bringing ‘*rezeki*’. These findings are consistent with what we might expect given the regulatory and economic context of elasmobranch trade in Aceh, Indonesia. It remains legal to catch and domestically-trade hammerhead sharks and wedgefish, both of which have commercial and subsistence value, while whale sharks are legally and customarily protected (Booth, Squires, et al., 2021; Hau et al., 2018; Simeon et al., 2020).

Figure 5. Results for each study species mapped onto the bycatch spectrum

Implications for behaviour change interventions for bycatch mitigation

This diagnosis sheds light on potential behaviour change interventions to reduce (by)catch of wedgefish and hammerhead sharks. Firstly, from a technical perspective live-release may be effective for wedgefish due to their relatively higher survivability, while avoidance measures (e.g., spatio-temporal closures) may be more effective for hammerheads. However, in both cases, there is need to change fishers’ behavioural and normative beliefs to promote uptake of these behaviours. Since behavioural beliefs for wedgefish and hammerhead sharks were primarily focused on material outcomes – such as money and food - incentives or compensation may be required to re-shape fishers’ beliefs regarding the outcomes of bycatch-relevant behaviour. For example, performance-based compensation for live release (Wosnick et al., 2020) or marine

340 conservation agreements which ‘buy out’ fishing rights in spatio-temporal closures (Sykes et al., 2018) could
341 create positive outcome evaluations for bycatch mitigation, since lost income would be compensated for. In
342 parallel, lessons for salient and culturally meaningful conservation messaging can also be drawn from
343 positive behavioural beliefs regarding bycatch mitigation for whale sharks. For example, fishers support live
344 release of whale sharks because they believe whale sharks play an important role in maintaining the health of
345 fish populations (i.e., “*dia bawa ikan kecil*”). Developing local campaigns for wedgefish and hammerheads
346 using similar messaging – e.g., explaining they are close relatives of whale sharks, and sharing salient
347 messages such as “*kami bawa ikan kecil juga*” (we also bring the small fish) – could help to re-shape the
348 intrinsic value of wedgefish and hammerheads.

349

350 In parallel, positive normative beliefs for bycatch mitigation could be promoted through several avenues.
351 For example, the *Panglima Laot* plays an important role in establishing legitimate rules and norms for fisher
352 behaviour in Aceh (Quimby, 2015), while religious beliefs (e.g., concepts of *rezeki* and *mubazir*) also shape
353 fishers’ relationships with marine animals. Therefore, the local *Panglima Laot* and religious leaders could
354 play important roles as a trusted messengers or block leaders for influencing social norms regarding marine
355 conservation (Abdelzaher et al., 2019; Cinner, 2018; De Lange et al., 2019; Veríssimo et al., 2020). In
356 addition, social recognition for bycatch mitigation such as non-monetary rewards, or local competitions
357 which generate positive peer pressure or group-level incentives, could also help to re-shape normative
358 beliefs (Kotchen & Segerson, 2020; Nyborg et al., 2016).

359

360 More broadly the data also indicate how extrinsic incentives (e.g., food and income) and culture and
361 customary institutions can interact to both help and hinder marine conservation. Since whale sharks bring
362 *rezeki* and are customarily protected, fishers support pro-conservation behaviour for this species. However,
363 other catches are *rezeki*, and releasing them is *mubazir*, so fishers are disinclined to avoid or release them.
364 These intrinsic and normative factors also interact with desires for material well-being. For whale sharks,
365 they are a protected species with “no market” and “not for consumption”, therefore social norms and
366 economic expectations act synergistically to drive pro-conservation behaviour. Whereas for wedgefish and
367 hammerheads, intrinsic and extrinsic incentives act synergistically to drive positive beliefs regarding
368 exploitation. These findings also relate to broader behavioural economics literature on interactions between
369 intrinsic and extrinsic incentives, and situations where expectations regarding economic or material

outcomes can either crowd-in or crowd-out social norms, depending on the context (Cinner et al., 2021; Gneezy et al., 2011; Grillos et al., 2019). In Aceh Jaya, well-designed economic incentives or compensation schemes for bycatch mitigation may help to crowd-in existing social norms for ocean stewardship.

Discussion

We have presented the Theory of Planned Behaviour (TPB) as a socio-psychological approach for understanding fishers' salient beliefs regarding bycatch and identifying facilitators and barriers to adopting bycatch mitigation practices. We have also illustrated the utility of the TPB via a simple belief elicitation study in a small-scale fishery in Indonesia, to show how it can be applied to gather salient and culturally relevant information that can be used to design behaviour change interventions for bycatch mitigation.

Future applications of the spectrum of bycatch and the TPB could help to advance the use of behavioural sciences in marine research (Andrews et al., 2021), and support the delivery of more effective and socially-just marine conservation interventions, which are tailored towards the socio-economic realities of small-scale fisheries (Bennett et al., 2021; Cinner, 2018). For example, as we have illustrated, this approach can help to identify situations where social and economic instruments – such as incentives or trusted messengers – may be needed to encourage uptake of technical fixes for bycatch mitigation (Booth et al., 2019; Cinner, 2018; De Lange et al., 2019). It can also highlight specifically which beliefs or combination of beliefs need to be targeted, to design integrated interventions, for example with a mixture of economic and norms-based solutions which can act synergistically to address multiple barriers and crowd-in pro-conservation behaviour (Booth et al., 2020; Gneezy et al., 2011; Grillos et al., 2019). Our practical experiences during this study also highlighted how using the TPB to ask indirect questions about bycatch-relevant behaviour revealed much richer information than directly asking about motivations regarding catching endangered species. For example, on direct questioning about why fishers catch wedgefish and hammerheads, fishers typically respond with “*it's just bycatch*”, however questions about underlying beliefs reveal the important socio-economic roles of these species in fisher's overall livelihood strategies.

Despite these opportunities, challenges and limitations remain. For example, while the TPB has previously been used to reliably predict other pro/anti-social and environmental behaviour, the relative predictive

399 power of the different belief measures within our belief elicitation study remains untested. In the future, TPB
400 surveys of larger samples of fishers across multiple sites, combined with data on real bycatch outcomes from
401 landings surveys, would enable robust statistical modelling to evaluate the predictive potential of the TPB
402 for diagnosing drivers of bycatch, and the relative influence of attitudes, subjective norms and perceived
403 behavioural control on actual fisher behaviour and bycatch performance (e.g., as previously applied to
404 identify determinants of and predict recycling behaviour (Nigbur et al., 2010; Tonglet et al., 2004)). In
405 addition, while the TPB can help to identify intervention points for behaviour change interventions, it
406 cannot necessarily account for complex and unexpected feedbacks that could occur in real interventions (e.g.,
407 crowding-in vs. crowding-out) or via dynamic external influences (e.g., fish prices and macro-economic
408 conditions). One option could be to use the belief elicitation study in Aceh Jaya as a baseline, and then
409 conduct a follow-up study in the future following an intervention, to test whether beliefs, intentions and
410 behaviour changed as expected (Dunn et al., 2020).

411

412 In summary, we reiterate the need to understand the human dimensions of bycatch, especially in SSFs, for
413 more effective and socially-just marine conservation (Andrews et al., 2021; Bennett et al., 2021; Campbell &
414 Cornwell, 2008). When endangered marine species form important components of coastal livelihood
415 strategies, technical fixes alone will be insufficient to deliver conservation outcomes. Rather,
416 interdisciplinary approaches are needed to align conservation objectives with positive outcome expectations
417 for fishers.

418

419 Our bycatch spectrum combined with the TPB could be easily applied for understanding and managing
420 bycatch in other fisheries. This would help to advance the use of behavioural sciences in conservation, and
421 promote action-focused conservation research which moves beyond describing states and mechanisms,
422 towards creating social and behavioural change (Andrews et al., 2021; Balmford et al., 2021; Williams et al.,
423 2020). Moreover, by focusing on understanding perceptions of fishers, and identifying salient beliefs which
424 drive overexploitation or protection of marine species, the TPB can identify common interests and conflicts
425 of interest between fisheries and conservation objectives, and thus create opportunities to work towards
426 negotiated solutions, which respect the needs and rights of small-scale fishers. As such, wider adoption of
427 socio-psychological approaches could also respond to calls for advancing equity in marine conservation
428 (Bennett et al., 2019, 2021), and we encourage researchers, managers and decision-makers to think more

429 holistically about bycatch, and incorporate social and behavioural methods into designing bycatch mitigation
430 interventions in the future.

431

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439

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