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Pressures on Egyptian Red Sea fisheries from the artisan fishers' perspective

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Pressures on Egyptian Red Sea fisheries from the artisan fishers' perspective

Rehab Farouk-Abdelfattah [a,b], Pia Schuchert [c], Keith D. Farnsworth [a,*]

[a] Queen's University Belfast, School of Biological Sciences, 19 Chlorine Gardens, BT9 5DL, Belfast, United Kingdom
[b] National Institute of Oceanography and Fisheries, NIOF, Cairo, Egypt
[c] FAEB, AFBI, 18a Newforge Lane, Belfast, BT9 5NU, United Kingdom

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ABSTRACT

The Egyptian Red Sea (ERS) supports artisanal, commercial and recreational fisheries, managed using a summertime closure, not applied to recreational fishing. Stock status is little known and management options are severely limited. To inform future management, we report the results of a questionnaire survey of artisan fishers from four Red Sea ports, collecting basic socioeconomic and fisheries data: fleet characteristics, self-reported landings, plus attitudes towards current management. Relationships among catches, technical and social categories and categorised attitudes were analysed using ordinal and multinomial logistic regressions. Median income of ERS artisanal fishers was 54% of the mean income from work in rural Egypt in 2020. Almost all respondents reported declining catches (61% blamed "overfishing") and most were pessimistic (43% expected to remain fishing in 10 years time). The seasonal closure was poorly supported by artisanal fishers: 75% claimed it contributed to declining resources. The timing of the closure, intended to protect spawning fish, aligned with published spawning seasons for some, but not all important species. 66% of fishers identified this mismatch as the reason for policy failure. High dissatisfaction rates risk non-compliance: e.g. 23% of those interviewed switched to 'recreational' fishing during the closed season. Most artisan fishers of the ERS are in a precarious economic position, facing a declining resource, under management that few support, with concerns about the long term future for their livelihood. We suggest transition to a participatory approach with data-driven co-management as a long term solution.

1. Introduction

Artisanal fisheries provide a substantial portion of the human demand for animal protein (FAO, 2016, p71) and employment and income (Béné et al., 2007) in many coastal communities of low and middle-income countries. They also make significant social and cultural contributions (FAO, 2022) so are important even in more developed countries (Stoll et al., 2023). Potential for conflict with both commercial (Belhabib et al., 2019; Warren and Steenbergen, 2021) and recreational (Kadagi et al., 2020) fisheries highlights their vulnerability. Fisheries management faces conflicting requirements when different fishery sectors share the same space and artisan fisheries often loose out as policy is more frequently tailored to match requirements for the commercial sector (Warren and Steenbergen, 2021). Small scale fisheries are typically data-poor, especially in low and middle income countries (FAO, 2015). Many countries, especially in Africa and the Middle East, have insufficient data to complete an assessment of U.N. Sustainable Development Goal (SDG) target 14.b.1 (FAO, 2023b). Most artisan fisheries there do not even feature in the SDG data yet (FAO, 2023a), despite the importance of their fisheries to food security, socioeconomic stability and their high rate of depleted and declining stocks (Belhabib et al., 2019).

Here, we report on an example of a data-poor artisan fishery from Egypt, where fisheries management has not changed substantially in forty years (Samy-Kamal, 2020). Our focus is on the perceptions and attitudes of the artisan fishers towards the prevailing fisheries management practices and their economic circumstances and experience of fishing in the Egyptian Red Sea (ERS). Perception here means a subjective account of the fisheries, economic and social conditions from the point of view of an interviewed fisher as reported to us using the questionnaire instrument described in Methods below. Worldwide, the artisan and small-scale fisheries of low and middle income countries are often found to be vulnerable and marginalised (Macusi et al., 2023; Nayak et al., 2014; Teh et al., 2020). Social survey of artisan fishers can be a first step towards their inclusion in fisheries management policy and has been used in pursuit of resilience (Macusi et al., 2023), inclusive governance (Eriksson et al., 2016) and fishers' wellbeing (Onumah et al., 2023).

* Corresponding author.
E-mail address: k.farnsworth@qub.ac.uk (K.D. Farnsworth).

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Our longer term aim is to develop participatory adaptive fisheries management (d'Armengol et al., 2018) and the starting point is to gather basic quantitative information about the artisanal fishery and the attitudes of fishers to current regulations, their socioeconomic conditions and prospects for sustainable fishing. To that end, we set out to find (a) the composition of the fishery in terms of boat sizes and gear used and distribution among home ports; (b) the economic viability of fishers in terms of income from fishing and associated costs; (c) fishers' views on the regulations, including their awareness of them and levels of agreement with their principles; (d) perceived problems concerning the fishery and fishers' confidence in the future prospects for artisanal fishing in the ERS. Note that since all artisan boats were found to be targeting the same assemblage of fish, resolution to the level of métier was redundant, hence we refer to combination of boat size and gear carried as *gear-class*. We collected data from a face-to-face questionnaire survey, supplemented with literature search (e.g. for fish species spawning dates) and we analysed the data, seeking patterns in the distribution of responses among classes of fisher (boat owner or crew), gear-class and home port.

2. Methods

2.1. Study area

We focused on the middle Egyptian coast of the Red Sea (Fig. 1) – recognised for its artisanal fisheries sector (GAFRD, 2021) – and conducted interviews in the two port areas that host the majority of artisan fishers (Hurghada and Safaja). In 2019, Hurghada fishing ports contributes 25.4% of all landings in the Red Sea, which amounts to 7979 tons, and Safaja accounts for 5.3% with 1654 tons (GAFRD, 2021): we were limited to these by logistic restrictions at the time of surveying the fishers. The small scale artisan fisheries (Rousseau et al., 2019; Smith and Basurto, 2019) coexist with commercial and recreational fishing fleets (Tesfamichael and Mehanna, 2016). The artisanal fisheries are economically and socially important in the ERS according to the statutory fisheries management authority in Egypt: the General Authority for Fisheries Resources and Development (GARFD) 2021. The FAO describe ERS artisan fishery as a "*long standing traditional (artisanal) fishery that exploits coral reefs spreading along the coast and in the Gulf of Aqaba ... where fishing grounds are relatively shallow (≤70* m)" – FAO (2010). Artisan fishers in the area operate gillnets, trammel nets and longlines from boat that are smaller than 12 m LOA. "*Larger vessels of medium size (12–24 m LOA) and larger (>*24 m *LOA) use bottom trawls and purse seines*" – FAO (2010). Samy-Kamal (2015) provides further detail, particularly of the catch composition of Egypt's fisheries.

The FAO described the management of the fisheries as "difficult" due to "unreliable" and patchy coverage of catch data, with little or no effort or socioeconomic data and a "weak" institutional framework (FAO, 2010). There is no published evidence that the situation has appreciably changed since 2010. Currently, the Egyptian Red Sea fisheries are managed by GAFRD who issue licences, direct fishery cooperatives, develop and implement management policy, the primary instrument of which is a seasonal closure from May to August (inclusive) (Samy-Kamal, 2015). This was originally established on a consultative co-management basis through an administrative committee consisting of GAFRD, the Egyptian Coast Guard and the Ministry of the Environment and the Co-operative Union of Aquatic Resources (Samy-Kamal, 2020). During the closure, recreational boats are permitted to operate, but only fish for personal consumption (Samy-Kamal, 2020). Recreational fishers are now restricted to one day fishing per trip and only permitted to use long lines. For other fishers, a minimum gill net mesh size is specified as no less than 7 'squeezed' diamonds within 50 cm, (Ministerial decision No. 447 of the year 2012 – Samy-Kamal, 2015). There is provision in the regulations for additional localised temporary closures to protect stocks.

Table 1
Sampling strategy of the survey: numbers of individuals questioned by geographic location; with one individual per boat.

Port name	Number of boats[a]	Planned surveys	Conducted surveys	% surveyed
Safaja	98	16	18	18
Sakkala[b]	394	66	43	11
Al-Dahar[b]	134	22	14	10
Areeda[b]	108	18	36	33

[a] From GAFRD (2021).
[b] Ports within the city of Hurghada, figures based on Administration Office records.

2.2. Sample strategy and data collection

The sampling frame consisted of all artisan fishers associated with the ports listed in Table 1, including those who had left fishing within the past five years as well as migrant workers (defined as fishers from a province outside the Red Sea Governate) associated with boats registered in those ports. The ports selected are the four largest on this coast from which artisan fisheries operate in the ERS: in 2019, ports in Hurghada contributed 25.4% of all landings in the Red Sea (7979 tons) and Safaja contributed 5.3% (1654 tons) (GAFRD, 2021).[1] Respondents were self-selected (one volunteer per boat) from crews as they arrived in port. We ensured only one participant per boat was interviewed to avoid pseudo-replication and all interviews were conducted separately and in neutral locations to avoid collusion and contextual bias. Sample size was based on power analysis using data collected in a pilot study for discrete and count statistics with 90% C.I. (Supplementary Material), giving a target of 120 independent interviewees. (No estimate of the total population of artisan fishers operating from Egypt in ERS was available).

In person (face-to-face) interviews were conducted during September to October 2022. The interview questionnaire (Supplementary Material) comprised three sections and took typically 25–30 min to complete. Section 1 built a description of the fisher and their fishing activity, including the boat and fishing gear used. Section 2 gathered basic economic data concerning their fishing activity: typical revenue from landings, total costs per trip, and self-reported present and past fishing effort and catches. Section 3 collected data about the interviewee's knowledge of – and views on – the current fisheries management regulations, especially the implementation of a seasonal closure, using a mix of open questions and ordinal descriptor scales. All interviewed fishers completed the questionnaire.

Prior to conducting the interviews, participants were provided with a description of the study's objectives and were assured of the confidentiality of their responses. The study's goal was stated as "*to assist in developing appropriate management*". The face-to-face interviews were conducted in Arabic, during which information was recorded on a standardised form and subsequently translated to English by the researcher. Responses were anonymised and data was retained only after obtaining signed consent from the interviewee. The method and content of questionnaires were granted approval by the Queen's University Belfast Research Ethics Committee prior to implementation and data was managed under the UK implementation of the General Data Protection Regulation (The Data Protection Act 2018).

All variables and their corresponding definitions are shown in Appendix A. Table 7 and the levels of nominal, ordinal and binary variables are given in Appendix A. Table 8.

[1] The port of Shalateen, responsible for 9.8% of landings (3077 tons), is also significant but was not accessible during the study. Although Alquesier represented 10.4% of landings in 2019 (3263 tons), the number of active boats was found to have substantially declined since then, so it was not included.

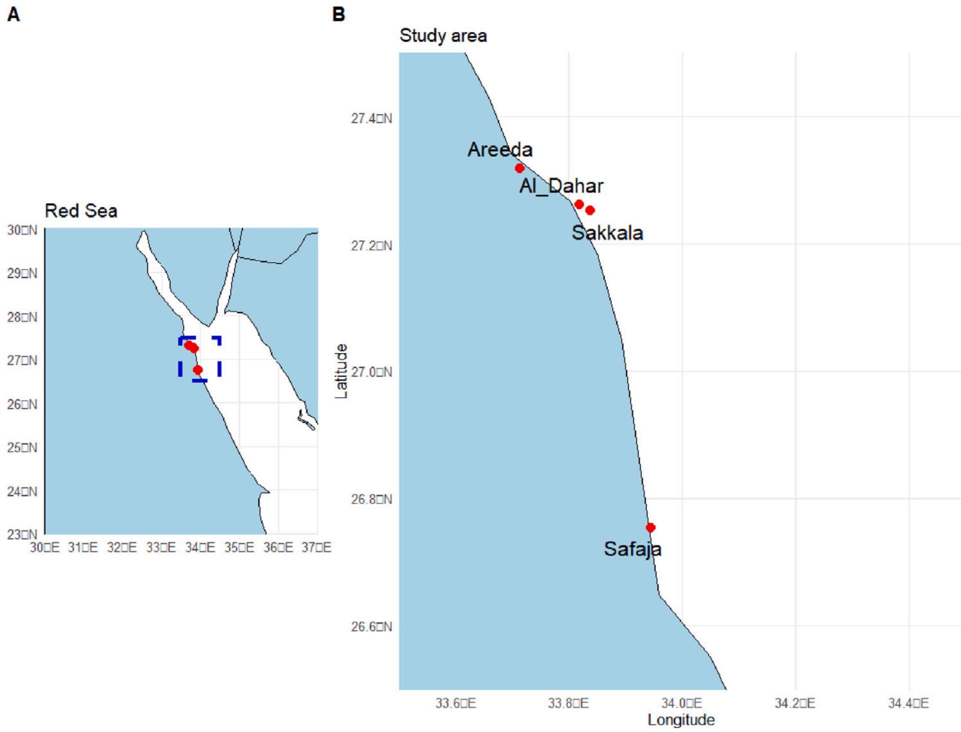

Fig. 1. Map with global grid for location, showing the main artisan fishing ports from which respondents were selected. Numbers of boats in each port is given in Table 1.

2.3. Data analysis

Interviewed fishers were categorised by ownership (boat owners or crew), origin (local or migrant), age, and the gear of the boats they worked. We also categorised boats into gear-classes by the combination of gear type and boat length.

Responses to open-ended questions were categorised by interpretation into ordinal variables with levels defined in Table 8. Ordinal logistic regression (OLR) was then used to test models for ordinal variables, especially to predict subjective responses from interviewees, based on their other answers. OLR effectively fits a set of binomial logistic regressions using the cumulative probability, following the order of levels in the dependent variable and is well established for modelling ordered categorical variables. Where variables could not clearly be ordered, we used multinomial (nominal) logistic regression (MLR), using the baseline-category logit model, i.e. multiple binomial logistic regressions together acting as a classifier. Further details of statistical methods are presented in Appendix B.

3. Results

3.1. Characterisation of the fishery

Of 120 fishers surveyed, 111 completed the survey and the interviewed fishers were generally cooperative and keen to express their views. We categorised them as migrants or locals, and boat-owners or crew (Fig. 2.A, B). Notably, in contrast to the findings of Areeda and Al-Dahar, which identified a predominantly migrant workforce, the majority of workers in Sakkala and Safaja were locals. Of all, 79% inherited the trade (family-motivated), the remaining 21% had no artisanal fisher parents (self-motivated). Their age distribution is shown in (Fig. 2.C) which markedly contrasts with the Egyptian population as a whole that shows fairly steady decline with age classes (PopulationPyramid.net, 2023). The sample of fishers was well distributed among fishing gear deployed: we interviewed 35 longliners (32%), 48 gillnetters (43%), 25 multi-gear users (23%), and 3 other gear users

Table 2
Summary of fishing boats by gear type, showing the total number of vessels and the average percentage for each gear type across all the four ports.

	Gear type	Number of boats	Percentage (%)
1	Gillnets	48	43
2	Longlines	35	32
3	Multi-gear	25	23
4	Other	3	2

(Table 2). We found 55% of fishers were members of fishing cooperatives — only half of whom agreed that cooperatives provided services to fishers, such as loans for boat and motor maintenance. For sixteen of the fishers, their children (all male[2]) already worked alongside them; a further seven expressed a wish for this, but 78% of them told us they did not want their children to follow them into the trade, citing "*pressures*" (including "*bad weather in the winter*", "*the low price of fish compared to the high cost of living*", and "*debts owed to wholesalers"*. OLR (see Methods) revealed two characteristics associated with the probability of passing the trade on to children (`FAM`). Compared to locals, migrants were less likely to encourage their children to join (odds ratio (OR) = 1.32) and boat owners were more likely to want their children to join compared to crew (OR = 2.08) (Appendix Table 9). Since 95% confidence for both ORs straddles 1, we tested univariate associations with χ^2 on cross-tabulation and found `FAM` may be associated with the fisher's origin (χ^2 = 6.42, df = 3, p = 0.09) and possibly with their ownership status (χ^2 = 5.83, df = 3, p = 0.12). `SUPPORT` and `PORT` were removed from the OLR model of `FAM` due to high multicolinearity, (VIF > 5.0). Catch per trip (`CPUEnow`), costs per trip (`COSTS`) and `GEAR` contributed no discernible effect, so were excluded.

All the boats belonging to interviewed artisan fishers were powered by an external 40 hp motor, though they differed in boat length and crew size. More than half were of 8–10 m LOA, with 22% of length

[2] Although we use inclusive language, we note that artisan fishing in the ERS is an entirely male occupation.

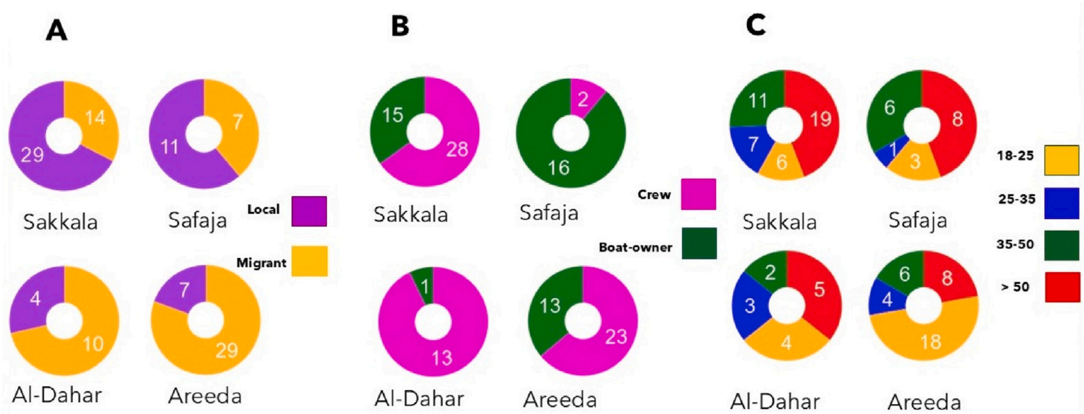

Fig. 2. Donut charts showing the demographics of surveyed fishers, grouped by A. origin of fisher (TYPE), B. ownership status (OWNER) and C. AGE profile. Each donut chart represents the distribution of categories in the sample from each port.

Table 3
Distribution of surveyed boats by length category (in meters) and categories of crew size.

Crew	Length			
	6–8	8–10	10–12	>12
2	2	0	0	0
2–4	7	7	3	0
4–6	10	48	17	0
>6	0	2	3	4

Table 4
Distribution of self-reported catch per trip (CPUE) (median with inter-quartile range (IQR)) among gear-class (gear ×boat length). Numbers of boats refers to those appearing in the survey sample, not the total fleet.

Boat Class	CPUE (kg/trip)
Gillnet 10–12 m	275 ± 250
Gillnet 8–10 m	175 ± 100
Gillnet 6–8 m	200 ± 250
All gillnets	**200 ± 200**
Line 10–12 m	150 ± 200
Line 8–10 m	150 ± 100
Line 6–8 m	200 ± 280
All long lines	**175 ± 170**
Multigear > 12 m	250 ± 100
Multi 10–12 m	325 ± 420
Multi 8–10 m	300 ± 50
Multi 6–8 m	175 ± 125
All multigear	**300 ± 150**

10–12 m. Four to six fishers per boat was the most common (75 cases) (Table 7). All the boats with LOA more than 12 m were crewed by more than six fishers, while the smallest boats (6–8 m) had fewer than six (Table 3).

Table 4 shows a combination of boat length, gear type and self-reported current catch per trip at the four ports studied. Gillnet boats generally caught more than longliners, which showed no increase in catch with boat length (indicating that boat capacity was not the limiting factor). A fifth of the respondents claimed to use multi-gear (defined as any combination of two or more types of longlines, gillnets, and/or traps) for fishing (Tables 2 and 4), even though that was prohibited by legislation (Samy-Kamal, 2020). As Table 4 shows, the multi-gear option provided higher catch per trip than single gear types. Respondents identified the primary target species of their boat and although some species are highly seasonal, targeting overall was well distributed among four main taxa: *Lethrinus nebulosus*; *Epinephelus summana*; Siganidae and Scaridae (we did not ask fishers to discriminate among species of scaridae (parrotfishes) or siganidae (rabbitfishes)).

3.1.1. Economics of artisanal fishing in the ERS

The artisan fishery operates for eight months per year (due to the four month closure), each boat making approximately 2.5 trips per month of typical duration 10 days, estimated from fishers' statements. We found that in every case, remuneration received by the fishers for each trip is determined by a proportionate allocation of the total catch. The individual's share of income varies among boats, but generally, fishing costs are deducted from the fish sale revenue of each trip. The remainder is typically divided by the number of fishers (including the owner, who acts as skipper) plus one. The extra share goes to the boat owner for the boat's maintenance, thus each individual fisher receives one share as personal income and the owner receives an additional share normally intended for overheads. Accordingly, we estimated personal annual income from fishing as the median income per trip multiplied by the expected number of trips made per year. The annual net income of boat owners was determined by deducting their taxes and boat maintenance expenses from their annual income from fishing of two shares per trip. Similarly, annual net income of crew was calculated by subtracting their personal licence fees and proportional share of costs from their income of one share per trip. Annual net income from fishing was estimated by multiplying per-trip net income by the estimated 20 trips per year. For comparison, we also estimated the number of trips per year needed to reach the mean annual income from work in rural Egypt, obtained from CEIC (2021).

Boat owners were paying an average of $US 115 for fuel; $US 21 for oil; $US 64 for food and $US 17 for ice per fishing trip of 10 days. The mean annual cost of taxes and mandatory insurance was $US 365. Wholesalers marketed the fish and close connections were maintained between the boat owner and a wholesaler who often provides short-term financial support to fund the fishing trips. This close relation may place fishers at a disadvantage over pricing for their catch: 25% of respondents complained that wholesalers control fish prices. Mean gross income per person per ten-day trip was $US 54, after costs of consumables (variable costs) were deducted, giving an annual mean income of $US 1040 per capita from fishing. The annual per capita mean income in Egypt was $US 1414 in 2015 and $US 2210 in 2020 (CEIC, 2021). The income from work in rural Egypt was $US 1226 in 2015 (CEIC, 2021) and using the Egyptian mean income to adjust for inflation, the mean rural income in 2020 was an estimated $US 1915, which we believe a more relevant comparison. Thus we estimate that annual per-capita income from artisan fishing in the ERS is about 54% of the mean income from work in rural Egypt. Fig. 3 shows the fishers' net income (annual income minus fishing costs) compared to the rural average. Income distributions were highly skewed so that median income is close to the lower quartile for both owners and crew. Net income of owners was less than crew because boat running costs often exceeded a share of net revenue. Only fifteen percent of

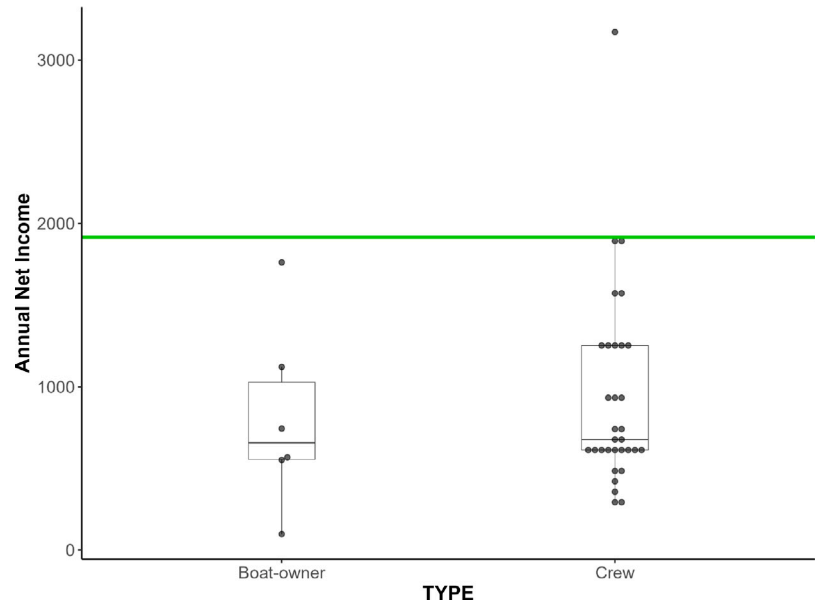

Fig. 3. A comparison between artisan fisher's annual net income from fishing and mean income from work in rural Egypt in 2020 (horizontal line) (CEIC, 2021). Note crew incur fewer fishing costs, hence higher potential net income — see text for details. (Currency in US $).

the respondents claimed an additional source of income, so that on the basis of 20 trips per year, using their self-reported income and costs, nearly all of them gain less than the mean rural income from work. Indeed, based on these figures, fishers would need to make approximately 35 trips per year to match the rural mean income, which for ten-day trips allowing three trips per month, would require fishing every month of the year with no time for rest or repair.

Fig. 4 A shows no overall relationship between self-reported current catch per trip `CPUEnow` (used as a surrogate for CPUE) and the self-reported net income per trip. A GLM with ownership as a factor showed no significant relationships between income per trip, catch per trip and costs, other than for the interaction term costs/catch per trip among crew (only), which predicted the intercept alone for income per trip ($p = 0.015$). There was no significant difference among gear types in income per trip (ANOVA F = 0.11, p = 0.89), thus, CPUE does not appear to be a clear driver for increasing effort. In univariate regression, Fig. 4B shows that self-reported current catch per trip was weakly associated with fishing cost per trip over all gears and ownership classes ($r^2 = 0.24$; p = 0.001). Gillnetters experienced highly variable catch per trip, but their costs varied little, around $US 160, so there was no discernible relationship between catch and financial effort. Longliners costs showed more variably among trips, but they achieved similar catches to the gillnetters, again with no discernible relation between trip-cost and catch per trip (compare to Table 4). It is possible that prices for different species/sizes caught help account for the poor relationship between CPUE and income, but we did not have price data to test for that.

3.2. Attitude towards the seasonal closure

3.2.1. Awareness and alignment with the closure's justification

All interviewed fishers showed awareness of the seasonal closure, but the majority, 81% of the respondents claimed no knowledge of a minimum gill net mesh size restriction. Fishers' knowledge of regulations did not significantly differ among ports (Kruskal–Wallis χ^2 = 2.4, p = 0.49). Alignment in stated reason for the closure policy was mixed (Fig. 5): 54 (50%) of those surveyed repeated the official justification for the closed season, i.e. "*to protect spawning fish*", but 26% gave different answers, some of which implied knowledge of the justification, but disapproval: "*It's just a formal procedure*", or "*It's for the spawning season, but not in the spawning season*".

In OLR analysis of `ALIGNMENT` (Appendix Table 10), we found crew significantly more likely to respond with the official justification for the closure than boat owners (Ordinal Logistic OR = 0.36). Owners may be well aware of reasons for the closure but could have used their answer to make a protest response. An interesting indication of this arises from the possible difference in responses among gear types used by the fishers: those who fish with multi-gear were more likely to positively identify spawning season as the justification than those using gillnets (OR = 0.55), while longline fishers were less likely than gillnet fishers (OR = 1.25) (see results for `SUPPORT` for further explanation). Older respondents were more likely to positively identify the justification than younger age groups (OR = 0.36). Fishers using the smallest boats (6–8 m) were less likely than those on larger boats to positively identify the justification, though the effect diminished as boat size increased (compared to 8–10 m boats OR = 0.27, but compared to boats >12 m, there was no difference). Univariate tests showed that `ALIGNMENT` was possibly associated with ownership status (`OWNER`) (χ^2 = 5.54, df = 4, p = 0.24), but (being underpowered for 8 degrees of freedom) failed to pick up an association with `GEAR` (χ^2 = 6.04, df = 8, p = 0.64). Multicollinearity tests for the OLR model of `ALIGNMENT` revealed `PORT` to be highly correlated with other independent variables (VIF > 5.0), so it was removed from the model. Fisher's origin (`TYPE`) was removed from the model after finding it contributed no discernible effect.

After respondents were informed of the official reason for the closure, 66% of them disputed the implication that all important species spawned during the closed period (Fig. 6). Not surprisingly, the most critical respondents were those who claimed the closure was just a formal procedure, most of whom thought fish migrate, making the closure irrelevant. A total of 39 respondents believed that fish populations migrate; 15 believed that fish spawned throughout the year and eight believed the fish migrate vertically to depths out of reach of their gear. Slightly over half of those correctly stating the justification for the closure believed that spawning of the main species takes place during the closed period.

Overall, the majority of respondents were sceptical about the spawning season justification and this raised the question of whether it could be better justified than their beliefs about spawning seasons. We tested that by comparing both the policy and fishers' views with published spawning dates for important species in the area (Table 5). Since several species spawn over more than one of the seasons, agreement

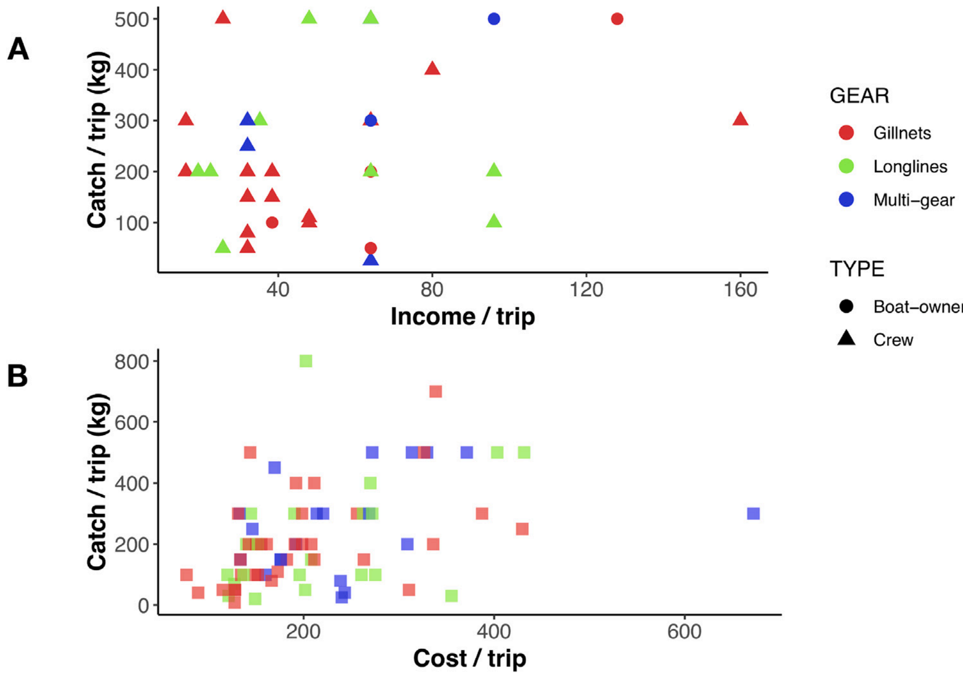

Fig. 4. Self-reported catch per trip (CPUEnow) in kg fish, plotted with self-reported net income per trip (A) and costs per trip (B). Fishers are categorised by gear used and by ownership category. (Currency in US $). Note costs are larger than net income, not gross income.

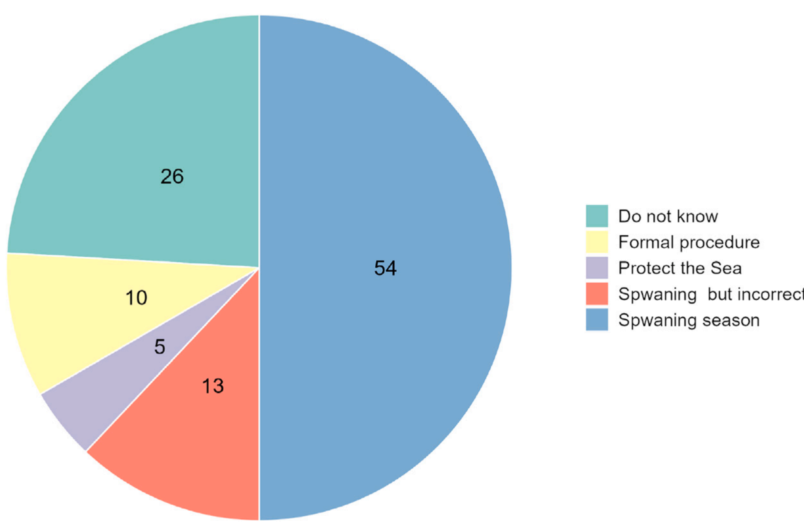

Fig. 5. Fisher's explanations for the seasonal closure. Out of 111 survey respondents, 108 contributed their responses. Half stated the official reason and 24% said they did not know. 12% knew it was to protect fish during spawning, but complained that it was misguided (see Fig. 6). 9% claimed it was just a "formal procedure".

between fishers' or regulator's estimates and the literature could be assessed either inclusively (agree if any of the published seasons are named in the estimate) or exclusively (disagree if any of the published seasons are not named in the estimate). Even on the inclusive assumption, neither regulations (Gwet's AC1 = 0.499, p = 0.012)[3] nor fishers (Gwet's AC1 = 0.532, p = 0.01) are close to the literature, though fishers appear a little closer than the regulations (the difference is not significant). On the exclusive assumption, regulations show no discernible agreement with the literature (Gwet's AC1 = 0.07, p = 0.58) and fishers estimates seem little better (Gwet's AC1 = 0.13, p = 0.37), though neither test was significant. On the same measure, fishers' estimates significantly disagree with those implied by the regulations (Gwet's AC1 = 0.37, p = 0.08), giving a quantitative explanation for their stated disbelief in the justification for the closure period.

The level of support for the official justification for the closed season (SUPPORT) was very strongly associated with ALIGNMENT ($\chi^2 = 40.9$, df = 16, p = 0.0006), corroborating the impression that many used their answer to ALIGNMENT as a protest. We built a multinomial logistic model for SUPPORT to examine potential explanations for its distribution among respondents. The first step was to perform a multicollinearity test, which showed that LENGTH and SATISFACTION were removed for multicolinearity (VIF > 5.0). Additionally, COSTS, AGE, and TYPE were excluded from the model because they showed no explanatory power.

[3] Gwet's AC1 is a more robust measure of agreement than Kohen's κ, but needs different interpretation. Its value is typically greater than κ and closer to the relative frequency of agreement (Vach and Gerke, 2023). Given one rater consistently stating "summer", Gwett's AC should be close to 1.0 for at least 'moderate' agreement.

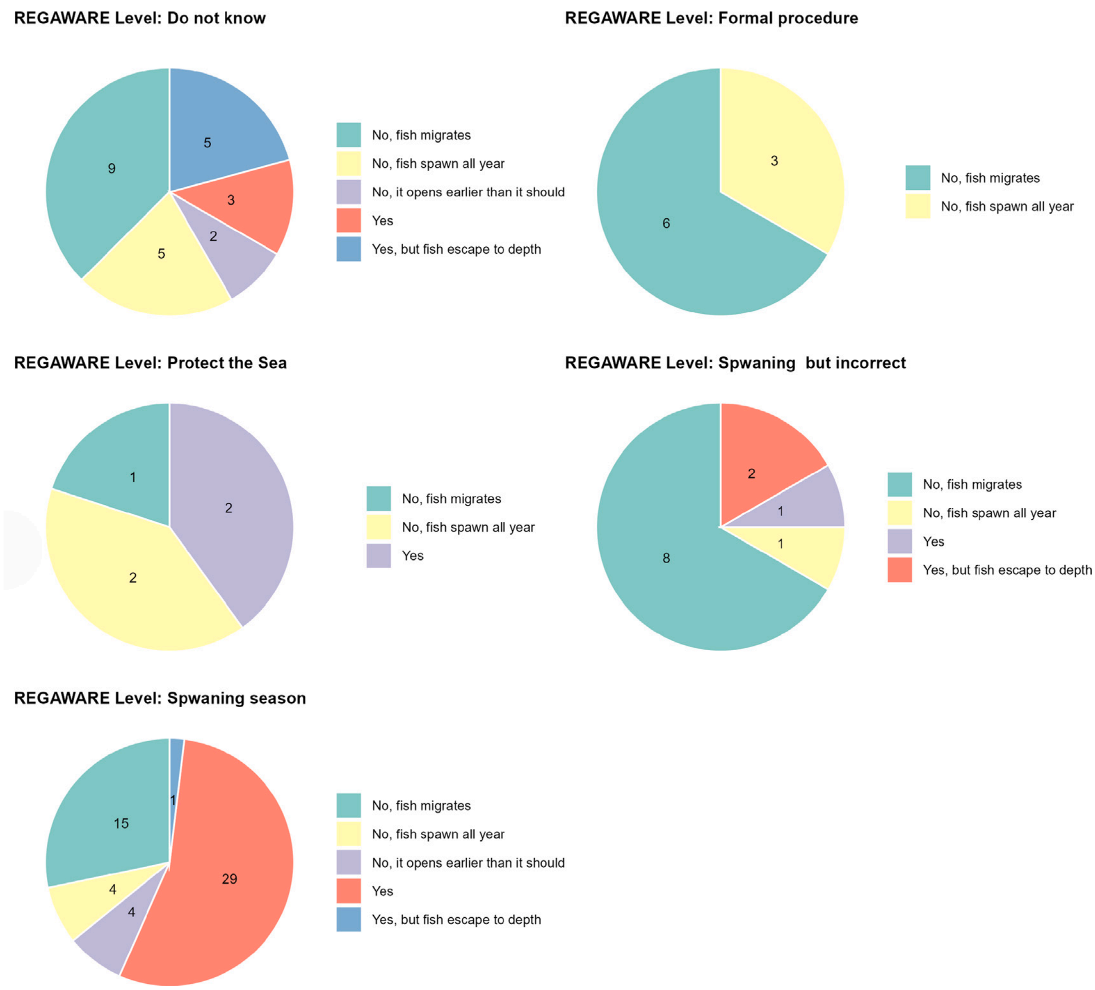

Fig. 6. Opinions expressed on the justification for the closure after respondents had been informed of it. Each pie shows the distribution among SUPPORT levels for a different responses to ALIGNMENT - plotted in Fig. 5. A substantial proportion, even of those who identified spawning season as the justification, were sceptical about it.

Table 5
Season for spawning of abundant commercial species drawn from scientific literature (taken as 'gold standard') vs. that implied by the closed season (regulation) and fishers' estimates. The regulation assumes spawning is in summer for all species, so the closure coincides with published spawning seasons for seven of the thirteen species. S = summer; A = autumn, P = spring; W = winter.

Species	Literature	Regulation	Fishers
Priacanthus hamrur	W (CMFRI, 2015)	S	S
Carangoides bajad	S-A (Grandcourt et al., 2004b)	S	W
Siganus rivulatus	P-S (Popper and Gundermann, 1975)	S	S
Parupeneus frosskali	P-S (Heneish et al., 2019)	S	P
Lethrinus mahsena	A (Carpenter and Allen, 1989)	S	S
Lethrinus nebulosus	S (Mahmoud, 2009)	S	S
Plectropomus marisrubri	W-P (Tamelander et al., 2008)	S	S
Epinephelus tauvina	P-S (Mohammed-AbdAllah et al., 2022)	S	S
Epinephelus summana	P (Osman et al., 2021)	S	P
Epinephelus chlorostigma	S (Ahmad et al., 2011)	S	P
Lutjanus bohar	Prolonged (Allen, 1985)	S	A
Acanthopagrus bifasciatus	W (Grandcourt et al., 2004a)	S	W
Rhabdosargus haffara	W-P (Osman et al., 2020)	S	W

Table 11 (Appendix) summarises the MLR model of (SUPPORT), comparing the clearly positive answer "*Yes*" with each of the negative answers in turn. Boat owners consistently showed less support for the justification for the closure than crew, with crew OR relative to boat-owner significantly <1 for all alternatives to answering "*Yes*". The probability of saying "*Yes*" was associated with CPUEnow and ALIGNMENT in every alternative answer (though results for the latter were occasionally spurious because the combination of answers to SUPPORT and ALIGNMENT could be rare – e.g. there were zero cases of "*Yes, but fish migrate to a lower depth*" with "*Spawning season*").

The answer "*Yes, but fish migrate to a lower depth*" was also associated with GEAR. Those who use multigear were significantly more likely to say that fish escape to depth than gillnet fishers (OR = 58.07) and longliners also showed this bias compared to gillnetters (OR = 9.7). Fishers who use longline gear, which usually targets fish at shallower depths than the gillnets, may have been including an element of protest in their explanatory response. We note that during the closed season, recreational vessels are only allowed to fish by longline, lending some credence to the claim that spawners may escape to deeper waters. However, in general, longliners and multigear fishers were also much

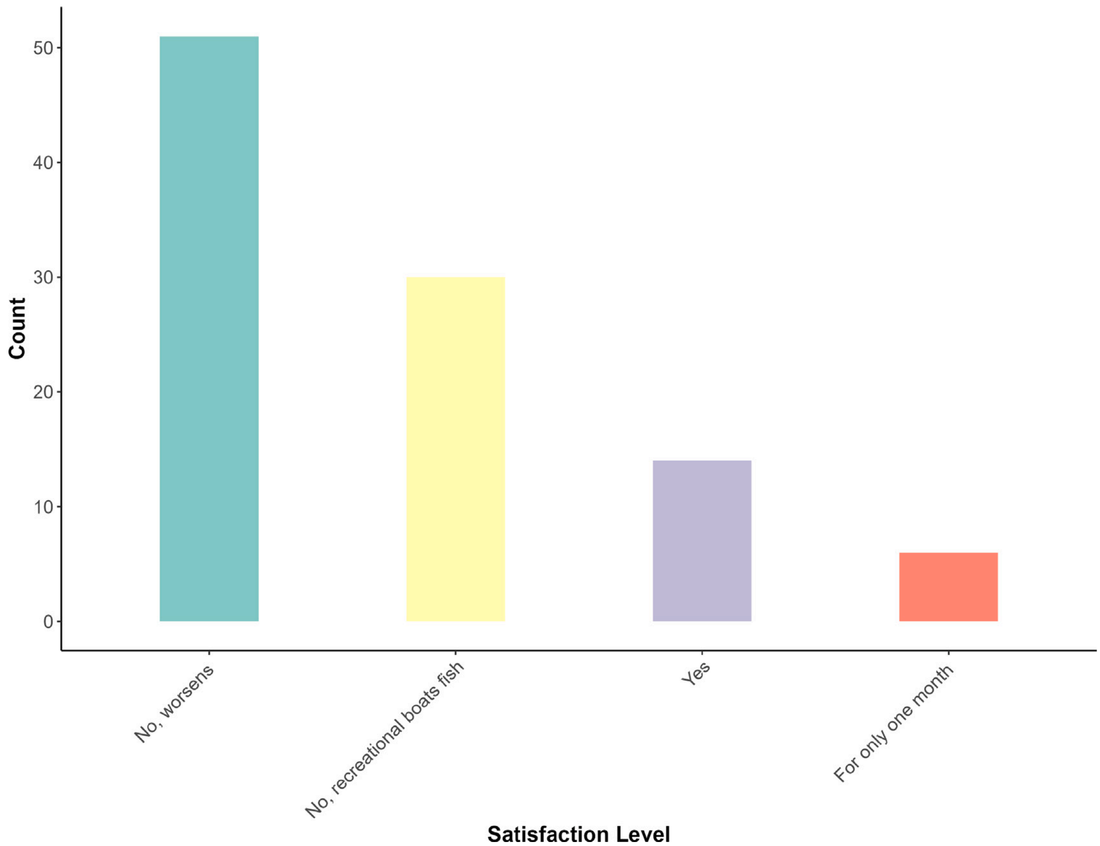

Fig. 7. Respondent's degree of satisfaction with the performance of the closure. Out of 111 those questioned, 96 stated an answer. Four distinct kinds of response were given, with the majority expressing dissatisfaction.

more likely, than gillnet fishers, to use an alternative (negative) answer than to say "*Yes*", leaving the gillnet fishers as those typically more likely to express support for the justification of the closure policy.

Those in the smallest category of catch per trip (0–50 kg) showed the lowest levels of support; fishers having larger catches tended to be less negative about the justification for the closure. However, fishers in the intermediate category (150–400 kg per trip) also showed a negative bias. Fishers in the categories 50–150 kg and 400–1500 kg were most likely to support the closure. This finding cannot be explained by simple correlation between gear and boat size and the catch per trip (see Table 4 and Fig. 4). Participants who most likely aligned with the official reason for the closure in ALIGNMENT were also more likely to support its justification. The sample size was too small to interpret any finer structure among answers to SUPPORT and ALIGNMENT.

3.2.2. *Satisfaction with the conservation effectiveness of the closure*

Even if fishers disbelieved the official justification for the closure, they may believe it had a positive conservation effect. However, the majority (80%) of respondents said that the closure had worsened their catch, 37% of which explained this by claiming that recreational boats were harvesting stocks in the closed season. A few (6%) thought the catch improved, but only for one month following the closure, leaving just 14% saying their catch was improved overall (Fig. 7).

The mean self-reported current catch per trip (CPUE) was 240 kg (maximum = 1500 kg) per 10 day trip, but the mean of respondents' recollection of their catch per trip in 2008 was 1014 kg (the maximum of 5000 kg, exceeds the capacity of boats in use, but multiple landings during a single trip have been observed). The variability in recalled catches is very large, as the spikes in the graph demonstrate, though recalled catches correlated with current catch per trip (Fig. 9.A). Interestingly, when smoothed recalled catch was plotted with current catch (Fig. 9.B), it followed a logistic-shaped curve, showing that those fishers catching more than the average of 200 kg (estimated from Table 4) thought they used to catch six or seven times as much, but if they now catch less than average, they thought they used to catch only about twice as much as they do now. Nevertheless, self-reported current CPUE was substantially less than the estimate of 14-years-ago for every fisher (Fig. 8): the median difference between CPUEpast and CPUEnow was 300 kg per trip. 57 (51%) of the respondents blamed overfishing for the decline in CPUE and (14%) blamed the seasonal closure (Fig. 10). 79% of respondents reported that overfishing was common, the remaining 21% claiming that it was not. Overfishing was attributed by respondents to the use of small-mesh-sized gears that could catch fish below the size of first spawning, the use of traps, and fishing by recreational boats. For comparison, Table 6 summarises the published results of stock assessments for common artisanal Red Sea fish species: it is likely that all are overexploited.

3.3. *Fishers' activities in response to the closure*

42% of the respondents claimed that they had given up trying to find work during the closure and instead stayed at home (unemployed), which they funded by borrowing money. 22% continued to search for alternative employment; 23% found precarious work as sailors on recreational boats (Fig. 11). This despite the fact that the engagement in artisanal fishing is strictly prohibited for any recreational boat or vessel (Samy-Kamal, 2020). Only 13% secured alternative work during the closure, such as working on farms or as taxi drivers.

The relationships between different closed-season activities and potential explanatory variables was analysed with an OLR (Appendix Table 12). Local origin fishers may have been more likely to engage in recreational fishing compared to migrants, though the effect was not significant. Individuals older than 50 were less likely to take recreational work compared to younger fishers, perhaps because more

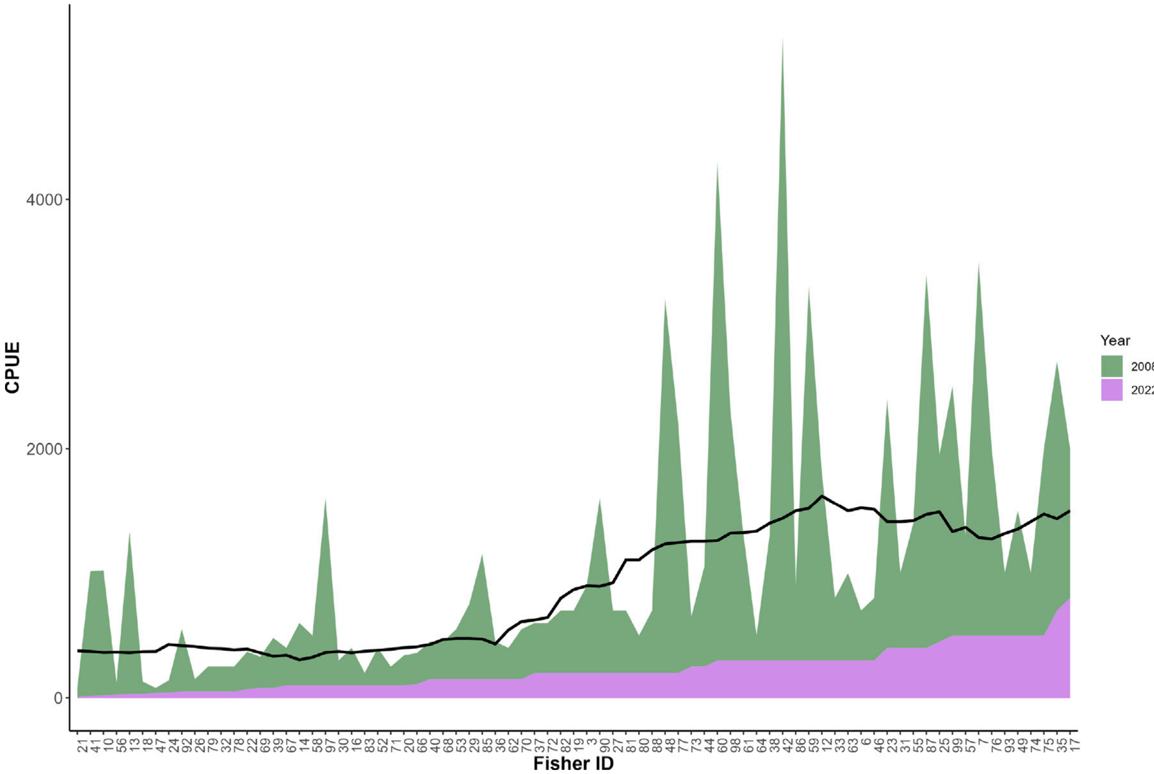

Fig. 8. The difference between catch per trip recalled from 14 years ago and current self-reported catch per trip. The *x* axis ranks individuals by their current (2022) CPUE. The thin black line shows historic estimates smoothed with a 25 point moving average (MA) filter. Fisher ID is an arbitrary label for anonymised fishers.

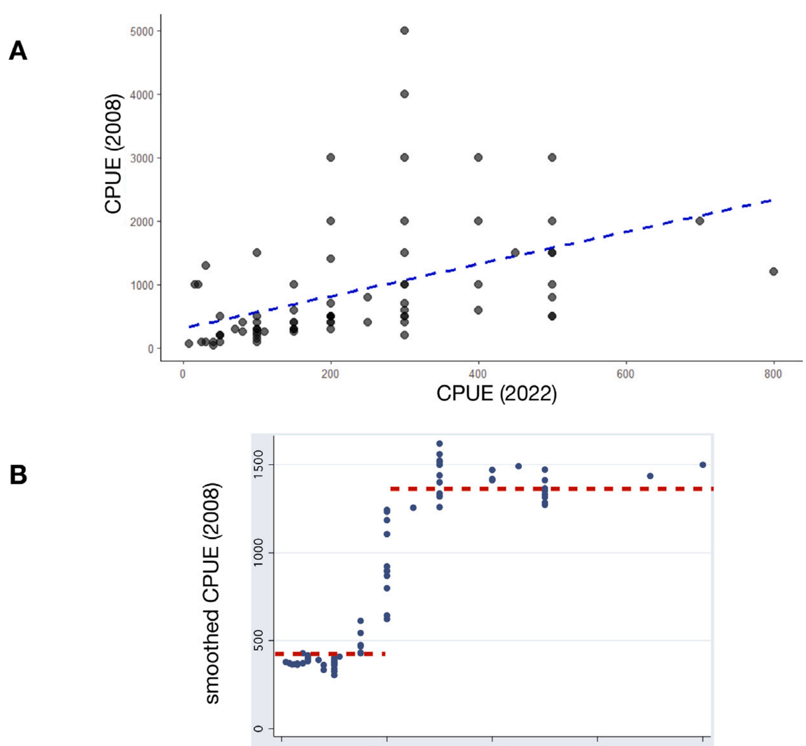

Fig. 9. A. Catch per trip recalled from 14 years ago CPUE(2008) plotted with current catch per trip CPUE (note the scale). B. Smoothed CPUE(2008), taken from Fig. 8, also plotted with current catch per trip showing logistic-shaped response in recollection (a logistic regression gives a perfect fit).

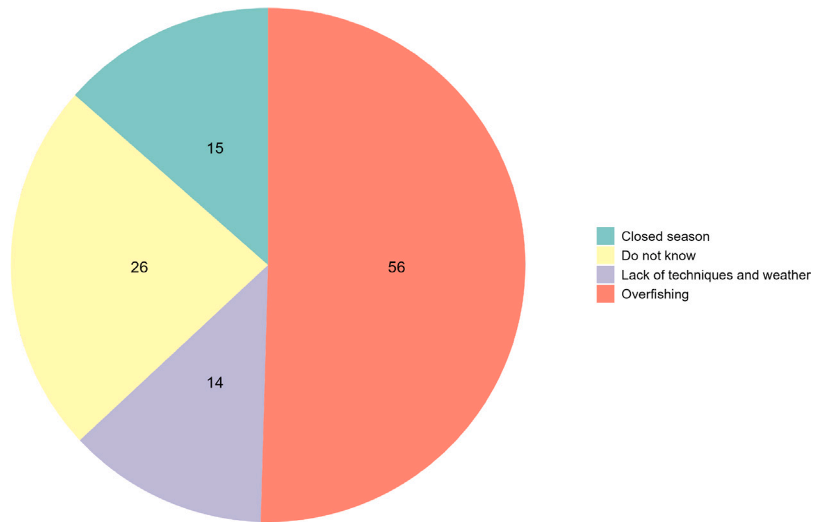

Fig. 10. Respondent's perspectives on reasons behind the decrease in CPUE. All 111 interviewees answered this question. Three kinds of reason were offered: (a) the closed season reduced fish populations; (b) inadequate fishing techniques, especially following climate change and (c) overfishing by some other fishers; the remainder of respondents were unsure.

Table 6
Stock status of species caught in the Red Sea, from published assessments (2012–2022). Over = overexploited; High = highly exploited.

Species	Stock assessment	
	Stock status	Reference
Acanthopagrus bifasiatus	Over	El-Mahdy et al. (2019)
Carangoides bajad	Over	Mehanna et al. (2016)
Siganus rivulatus	Over	Mehanna and Abdallah (2002) and Mehanna et al. (2018)
Parupeneus frosskali	Over	Farrag et al. (2018) and Sabrah (2015)
Mulloidichthys flavolineatus	Over	Farrag et al. (2018)
Mulloidichthys vanicolensis	Over	Farrag et al. (2018)
Rhabdosargus haffara	Over	El-Mahdy et al. (2021)
Sargocentron spiniferum	High	Mohammad et al. (2020)
Epinephelus summana	Over	Mehanna et al. (2019)
Cephalopholis argus	Over	Mehanna et al. (2019)
Epinephelus areolatus	Over	Mehanna (2005)
Lethrinus borbonicus	Over	El-Ganainy and Amin (2012)
Lethrinus microdon	Over	Mehanna et al. (2017)
Lethrinus variegatus	Over	Heneish and Sabrah (2021)
Lethrinus lentjan	Over	Zaahkouk et al. (2017)
Monotaxis grandoculis	Over	El-Mahdy et al. (2022)
Hipposcarus harid	Over	Amin et al. (2019)

of them stayed at home. Fishers claiming that the closure results in a one-month improvement in their catch per trip were much more likely to engage in "recreational" fishing compared to those who said it always worsened their catch (OR = 10.4). Those tending to work in the recreational fishery during the closure more often expressed the view that recreational fishery reduced their catches at other times, though the effect was not significant and we see no discernible relation between saying the closure improves catches overall and a tendency to work in the recreational fishery as opposed to staying at home or obtaining alternative work. We found no significant relation in univariate statistics between ACTIVITY and fisher's origin (TYPE) (χ^2 = 4.01, df = 3, p = 0.26), or age (χ^2 = 8.91, df = 9, p = 0.45), nor level of SATISFACTION (χ^2 = 8.32, df = 9, p = 0.50), though these are underpowered for the higher degrees of freedom. The multicollinearity test for this model of ACTIVITY led us to remove SUPPORT and PORT (VIF > 5.0). Additionally, the variables of OWNER, GEAR, CPUEnow and COSTS were excluded from the model because they showed no discernible relationship. Overall, it seems there was little evidence for any pattern in the choice of closed season activity.

3.4. Views on future prospects for artisan fishing

Given the evident dissatisfaction and difficulties with the closed season for many of the respondents, it is interesting to see how they view their futures in artisanal fishing. 55 of the respondents (>50%) told us they would like to leave the profession, but will continue because they have no alternative or because they did not know how to work in another activity. A third believed they would still be fishing in 10-years time (Fig. 12) and a few said they would continue if conditions and/or regulations improve (coded as '*continue with exceptions*').

Appendix Table 13 summarises an OLR model of expectations for future employment (FUT), showing significant association with TYPE and OWNER: migrants and crew were less likely to continue fishing than locals or boat-owners (OR = 2.89 and 3.04 respectively). The catch per trip category of 150–400 kg stood out as more likely to discontinue fishing, compared to those in the 0–50 kg category (OR = 3.38) – this category showed less support for the closure justification as well (see Appendix Table 11).

Fishers who rejected the rationale behind the closure (especially those believing that fish spawn throughout the year) were less likely to say they would continue as artisan fishers compared to those who supported it (odds ratio = 2.88). Interestingly, individuals who believe that the closure is ineffective because fish escape to depths beyond the reach of their gear were more likely to say they would continue as artisan fishers compared to those who showed the greatest support for the closure and this cannot be explained by correlation with GEAR, which was excluded from the model because it exerted no discernible effect. Participants who indicated dissatisfaction with the closure's performance due to recreational fishing, were more likely to expect to continuing fishing compared to those who said it worsens their catch (odds ratio = 0.39). Univariate cross-tabulation results show an association between FUT and fisher's origin (TYPE) (χ^2 = 8.41, df = 4, p = 0.08), but failed to detect significant effects of OWNER (χ^2 = 7.26, df = 4, p = 0.12); CPUEnow (χ^2 = 9.52, df = 12, p = 0.66); SUPPORT (χ^2 = 19.6, df = 16, p = 0.24), or SATISFACTION (χ^2 = 5.68, df = 12, *p*-value = 0.93), though χ^2 is underpowered given the large degrees of freedom for most of these. Multicollinearity tests for the ordinal model of FUT, led to only the variable PORT being eliminated from the model based (VIF > 5.0).

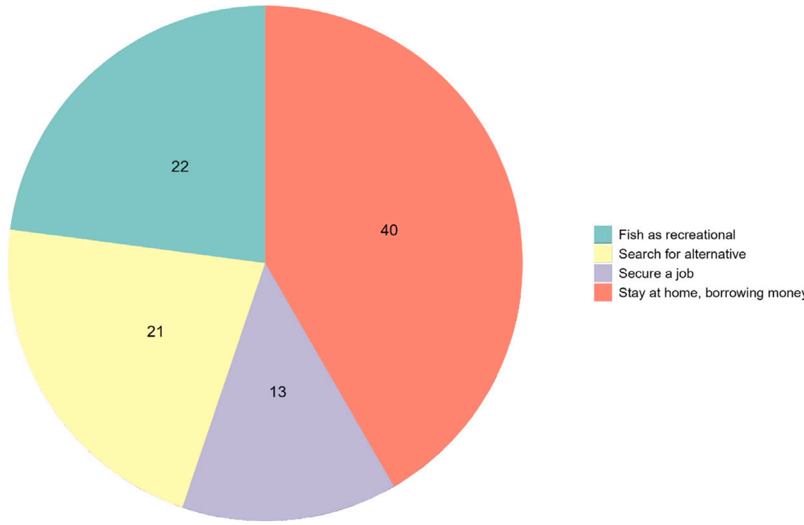

Fig. 11. Respondent's activities during the closed season. Out of 111 surveyed individuals, 96 answered this question. Four responses were provided: some stay at home, relying on borrowed money because they lack alternative work; others search for new opportunities; some fish on recreational boats; and a few already have another source of income.

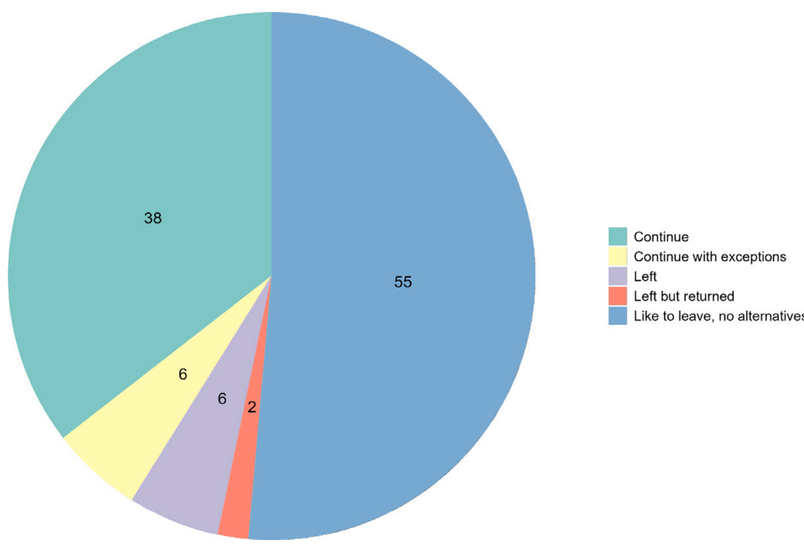

Fig. 12. Respondent's expectations for continuing fishing ten year's into the future. Out of 111 interviewees, 107 responded to this question. A few had left artisanal fishing already (purple), the majority want to leave, but felt they had no alternative to go to.

4. Discussion

Interviewed fishers left us in no doubt that most were dissatisfied with their present situation. The seasonal closure and what they perceived as unfair competition from recreational fisheries, were most frequently blamed for declining income. Most also identified overfishing as the main cause of declining stocks. Dissatisfaction and gloom over future prospects were most common among boat owners and least common among migrant crew and this may reflect the level of commitment to the local fishery; i.e. the 'stake' in the term 'stakeholder'. Boat owners typically take a double portion of the share of revenue from each fishing trip, though face much higher costs than crew and many also support loans, both for the boat and its equipment and (anecdotally) to cover periods of financial net-loss, especially during the closed season. This was reflected in net income, where crew tended to do better than owners. Nearly all respondents self-reported income from fishing was below the mean income from work in rural Egypt, suggesting that artisanal fishing in the ERS is economically marginal. Although according to Feidi (2009) and Tesfamichael and Mehanna (2016), the sector is small in comparison to Egyptian marine capture fisheries in the Mediterranean and ERS commercial scale fisheries (trawlers and purse-seine fishers with engine power >100 hp – FAO, 2010), it is socially and culturally important (FAO, 2022; Smith and Basurto, 2019; Warren and Steenbergen, 2021). Decline of the artisanal fishers' way of life in the ERS could potentially present costly social problems (Belhabib et al., 2019) as well as threatening the loss of a traditional culture (depicted in ancient Egyptian art).

Self-reported differences between present and past (14 years ago) catches varied considerably, but the direction of decline was consistent among all respondents. Although subjective, this provides evidence of decline in fish stocks across many important species, despite a long-running seasonal closure policy. Osman and Samy-Kamal (2023) found that the mean size of individual fish from the most valuable and abundant Red Sea species in markets was below the length of maturity, indicating the need to control size selectivity. Awareness of gear regulations (which were in place) was very poor and it seems that the emphasis of regulation has been placed on the seasonal closure. This implies that the closure has not protected fish stocks from overexploitation, a finding corroborated by species specific studies (Appendix Table 6).

Responses from interviewed fishers suggest that the seasonal closure policy may be creating perverse incentives to increase fishing effort and to cheat the regulations. Whilst awareness of the regulation was widespread, it was regarded as ineffective and technically unjustified by the majority of interviewees. The broad lack of support for the justification for the closed season is likely in part due to the mismatch between its timing and their beliefs regarding the timing of spawning, (neither of which matched well to the published spawning seasons of important species in the area), on which most of the artisan fishers interviewed had an opinion (Table 5). Fishers' local knowledge should not be discounted as a source of information for management policies (Rabuffetti et al., 2023). But in defence of the closure policy, since the majority of species at least included summer within their published spawning season, that is the most appropriate season for closure to protect spawning, if closure of one distinct season is to be used. The mismatch between that choice and fishers' beliefs about spawning suggests a gap in engagement and explanation on the part of regulatory authorities. Failing to appreciate the likely responses of fishers to management measures increases the likelihood of perverse and unexpected outcomes (Fitzpatrick et al., 2017) and lack of consultation with stakeholders risks missing important knowledge that could help in the design of fisheries conservation measures (Wilson et al., 2006).

More broadly, the formation of fishers' attitudes towards regulations is well known to affect compliance, particularly for small-scale artisanal fisheries where resources for enforcement are very limited (Oyanedel et al., 2020). The present case seems to rely heavily on 'deterrence and respect for authority', rather than 'moral support for the regulations' – using the typology of compliance motivations introduced by Gezelius and Hauck (2011) whose prescription was to develop the neglected 'precondition for compliance': in this case the empowerment of artisan fishers. Empowerment means more than 'engagement', (Jentoft, 2005), though in this case, we found no evidence even for that. Empowerment is most concretely implemented through co-management, which is strongly supported by international agreement through the UN (FAO, 2015, where Article 5.16 is particularly relevant to the ERS artisan fishery). Co-management has already been shown to encourage compliance (Jentoft, 2000; Caddy and Mahon, 1995). In situations where different fisheries and other interests compete for resources, a participatory framework designed to focus deliberation on equity and sustainability in resource governance has been effective (Estevez et al., 2020; Warren and Steenbergen, 2021). d'Armengol et al. (2018) reviewed the global evidence for co-management in small scale fisheries, finding that an enabling legal and institutional framework and a diversity of participating stakeholders predicted success in terms of both social and ecological goals. The current top-down governance of fisheries in the ERS has neither of those attributes. Rather than being 'engaged', we found the majority of artisan fishers alienated from management.

4.1. Challenges posed by recreational and other users of the ERS

Competition with recreational fisheries was thought by artisan fishers to significantly affect stocks, leading to a perception of unfairness, especially during the closed season. The (incorrectly) perceived freedom from regulation of recreational fishing was exploited by a significant minority of artisan fishers who switched to recreational fishing during the closed season. FAO (2015) emphasises the need to prioritise artisan fisheries in cases where larger commercial interests could dominate. Diving and snorkelling alone were projected to raise $US 10–29 million, from marine protected areas of the ERS (Colby, 2003); we do not have an estimate for recreational fishing, but it is likely that the recreational income to Egypt could far exceed the annual turnover of artisan fisheries. FAO (2010) reported 1206 trawlers and 328 purse seiners with engines >100 hp operating in the Red Sea on a more commercial basis and presumably with larger annual turnover than the combined artisan fleet. Potential conflicts of interest among these industries presents management difficulties whenever trade-offs are necessary and, following FAO (2015), we recommend that the economic vulnerability and social importance of artisanal fisheries be taken into account in management and regulatory decision making. We additionally interviewed three recreational boat owners and four individuals engaged in fishing activities on tourism boats. Interestingly, they all expressed concern over illegal fishing activity (despite indulging in it themselves) and called for more artisanal licences to be issued to alleviate the problem. All of these 'recreational' fishers claimed fishing to be their sole source of income. The self-reported mean catch from a 10-day trip made by these interviewees was 113 kg, (minimum 20 kg; maximum 300 kg), which if scaled up ((GAFRD, 2021) found 248 recreational boats operating in the area), could indeed present a significant removal. It would be useful to conduct further interviews among recreational and tourist fleet workers in a future study.

4.2. The way forward for future governance

Despite the lack of objective empirical evidence from scientific surveys, the overwhelming majority of fishers' reports of declining catches seems more than plausible and would continue a trend recognised by the FAO, quoted in Feidi (2009) and corroborated by Samy-Kamal and Mehanna (2023). This indicates an urgent need for stock management data covering the main species, but we must also recognise the severe resource limitations on fisheries management in the area. Governance is not helped by dependence on an overstretched top-down institutional framework, even though its intentions for ecosystem based fisheries management are good (in contrast to some other jurisdictions – (e.g. Alam et al., 2021)). The survey revealed an alarming economic precariousness among the artisan fishers, most of whose self-reported income from fishing fell short of the mean income from work in rural Egypt, particularly for the boat owners, who faced larger costs. It is tempting to put these two urgent problems together in a call for recruiting artisan fishers to perform a paid role in data collection for managing their stocks. The very weak institutional framework and widespread suspicion by fishers of authorities and their management policies suggests a desperate need for building cooperation and confidence. This could face formidable social challenges (e.g. Rivera et al., 2021), but it more directly reveals the challenges of gaining the trust of these fishers and of constructing an empirically-founded resource management policy that can gain their support. We noted that the fisheries co-operatives provided little support to artisan fishers, other than helping with paperwork and offering small loans. Co-operatives could be a focal point for participation in co-management and in the wholesale distribution of catches (as in McCay et al., 2014). The latter may be especially helpful for fishers, 21% of whom claimed that the commercial wholesalers unfairly set prices to their disadvantage. Co-operatives could also provide short-term finance and investment capital, if permitted by a legal and regulatory framework, as practiced in India (Arundhekar, 2017) and called for in Bangladesh (Alam et al., 2021). Fishers' concern over competition with recreational fishing were widespread, as often seen in touristic areas, (e.g. Romero Manrique de Lara and Corral, 2017), but unlike their study, in our case, major concerns over illegal, unreported and unregulated fishing (IUU) were not raised. Since the extent of IUU in the ERS remains unknown, the need for assessment is obvious.

Our results reflect the frustration felt from decades of poorly communicated regulations and emphasises the need for the empowerment of those affected in order to develop compliance (Gezelius and Hauck, 2011). The identified problems all point to the need for a participatory approach using genuine co-management (d'Armengol et al., 2018), as recommended by Partelow (2015) and Estevez et al. (2020). This could be framed in a wider context, as in Eriksson et al. (2016), where fishers were involved in guiding a more general ecological management plan, or it could be focussed directly on the sustainable management of the more important species, with fishers encouraged (and allowed) to be the stewards of the common resource, underpinned by local social cohesion (e.g. Tilley et al., 2019) and Romero Manrique de Lara and Corral (2017). Strong warnings come from previous studies, (e.g. Kaluma and Umar, 2021), where co-management has allowed elites to capture bottom-up management systems, especially where official authorities are ineffective. One answer to that problem might be an independent agent whose role is to coordinate self-management, acting as a technical advisor, enabling data-limited stock management tools to be used with catch-based data, collected by the artisanal fishers themselves, together with other sources of knowledge (Wilson et al., 2006), enabling adaptive co-management, an example of which was effective in reducing poverty in a Bangladeshi small scale fishery project (Haque et al., 2022).

The ERS artisan fishery is a long way from sustainable co-management, but a necessary first step is to recognise the communications and institutional shortfalls, conflicts of interest among stakeholders and the vulnerability and importance of the artisanal fishery as a socio-ecological system (Ostrom, 2009), following (e.g. Nayak et al., 2014). After four decades of near-static management, reform seems urgent. Priorities for a reformed fisheries management should include (a) a turnaround of the decline in economically important species; (b) recognition of the poor financial returns from fishing; (c) the introduction of appropriate and affordable fish stock monitoring and (d) arrangements to ensure stakeholder empowerment, especially through participation in management.

CRediT authorship contribution statement

Rehab Farouk-Abdelfattah: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Pia Schuchert:** Writing – review & editing, Supervision. **Keith D. Farnsworth:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Declaration of Generative AI and AI-assisted technologies in the writing process

No AI technology was used in the preparation of this manuscript.

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Appendix A. Data variables collected: definitions and dimensions

Referring to Table 7, the variable FUT describing the fisher's expectation of remaining in the profession for another ten years clearly forms an ordered set from '*already left*' to '*certainly intend to continue*'. The variable FAM describing the level of parent fisher's desire to have their children join the fishery is bounded by the extremes '*they already have joined*' and '*they already have a different job*', with an expressed desire for it, or against it completing an ordered set. SATISFACTION describes a fisher's view on the conservation effect of the closure policy, where the explanatory '*No, recreational boats fish*' is ordered above the more direct '*No, it worsens catches*'. The variable ACTIVITY indicates the fisher's occupation during the closed season, which we interpret as ordered on an axis of (one minus) the probability of transferring to the recreational fishery: '*Fish as recreational*' is the lower bound (100% probability) and '*Secure an alternative job*' is the upper bound (approximately zero probability), with '*Search for alternative employment*' posing a greater risk of transferring to the recreational fishery than '*Staying at home and borrowing money*'. The variable ALIGNMENT is more difficult to interpreted as ordinal: its answers consist of several ways of indicating awareness by describing the closure policy, together with '*Don't know*' which clearly indicates a lack of awareness. However, there is a sense of order in these answers if they are interpreted to represent different levels of vagueness and possibly hostility towards the policy ('*Formal procedure*' was often expressed with an implication of perceiving the policy as unjustified, while '*Protect the sea*' seemed often naive and vague). With this reasoning and interpretation, we categorised ALIGNMENT as an ordinal variable. Answers to SUPPORT describing belief in the justification for the policy amount to four ways to say it is wrong (with alternative explanations for why) and one way to say it is correct. Since we could not identify a clear ordering to this variable, it is treated as nominal. Finally, we treated CATCHDECLINE as a nominal for a similar reason to eliminate subjectivity from interpretation of the answers (Table 7).

Appendix B. Further details on statistical methods

Each OLR or MLR regression calculates the odds of a case having a particular category value in turn, relative to a baseline (reference) category, chosen in advance. This requires assuming independence from irrelevant alternatives (IIA) (changing one category does not affect the distribution among the others), so some care is needed in interpretation. IIA may be violated when the categories are alternative answers to a question of preference, but in the present study, the answers were responses to open-ended questions, which were subsequently categorised and therefore IIA violation is less likely because the categories were unknown to respondents (and researchers) at the time responses were made. Unfortunately the sample size here was insufficient to support the Hausman–McFadden test for IIA violation (which has very low power - Vijverberg, 2011). Both OLR and MLR analysis were performed as Generalised Linear Models (GzLMs) using logit link functions. Prior to modelling, we tested for multicolliniarity using pair-wise correlations and calculation of the Variance Inflation Factor (VIF) and eliminated redundant correlated independent variables (specified by VIF > 5.0, following Gunst and Webster (1975)). Model reduction then proceeded to exclude variables for which $p > 0.1$. OLR results were interpreted using the coefficient values for independent variables: these determine the log odds in the response variable for each independent variable relative to the reference category when all other variables are held constant (following e.g. Pyk and Abu Hatab (2018)).

For all categorical variables, we used χ^2 tests on cross-tabulated pairs as an adjunct to the logistic models. For assessing the degree of agreement between published spawning seasons and the season implied by the closure regulation and fisher's estimates of spawning seasons, we

Table 7
Definitions of data variables in the survey. (Currency originally recorded in £E, transformed by exchange rate 1 £E = 0.032 $US on 14-06-23).

Variable	Definition	TYPE
TYPE	The origin of fishers (local or migrant)	Binary
OWNER	The ownership status: (boat-owner or crew[a])	Binary
INHERIT	Whether the fisher inherited the occupation from their family, or was self motivated	Binary
PORT	Where the fisher's boat is registered	Nominal
LENGTH	Length category of fishing boat	Ordinal
GEAR	Type of fishing gear used	Nominal
FUT	Respondent's plan for 10 years ahead	Ordinal
FAM	Level of desire for their children to inherit the fishing occupation	Ordinal
CREW	Crew size category — number of fishers who routinely work on the boat	Ordinal
FUEL	Payment for fuel per fishing trip in $US	Continuous
OIL	Payment for oil per fishing trip in $US	Continuous
FOOD	Payment for food per fishing trip in $US	Continuous
ICE	Payment for ice per fishing trip in $US	Continuous
COSTS	Total costs per fishing trip in $US	Ordinal
CATCHDECLINE	Stated reasons for catch decline	Nominal/Pseudo-ordinal
CPUEpast	Stated catch per trip 14 years ago in kg	Continuous
CPUEnow	Stated current catch per trip in kg	Continuous and Ordinal
SATISFACTION	Level of satisfaction in the effectiveness of the closure	Ordinal
REGAWARE	Awareness of regulations in force	Nominal
ALIGNMENT	Level of accuracy in stated reasons for closure policy	Nominal/Pseudo-ordinal
ACTIVITY	Fisher's economic activity during the closure	Ordinal
SUPPORT	Level of support for the official justification for the closure	Nominal
COMPLIANCE	Stated compliance with the closure	Binary
OVERFISHING	Stated presence of illegal fishing in the area	Binary

[a] Boat owners acted as skippers and all owners were owner-operators.

Table 8
The levels of ordinal and nominal variables (including discretisation of continuous variables). Costs measured in $US as in Table 7 and CPUEnow is the self reported estimate of current catch per trip in kg fish.

Variable	Levels				
FUT	Left	Left but returned	Like to leave, no alternative	Continue with exceptions	Continue
FAM	Have alternative work	Not advised	Desire to join	Have joined	
CATCHDECLINE[a]	Don't know	Closed season	Lack of techniques and weather	Overfishing	
SATISFACTION	No, worsens	No, recreational boats fish	For only one month	Yes	
ALIGNMENT	Don't know	Formal procedure	Protect the sea	Spawning, but incorrect	Spawning season
ACTIVITY	Fish as recreational	Search for alternative	Stay at home, borrowing money	Secure a job	
SUPPORT[a]	No, fish migrate	No, fish spawn all year	Yes, but fish escape to depth	Yes, but it opens earlier than it should	Yes
COMPLIANCE	No	Yes			
OVERFISHING	No	Yes			
COSTS	32–96	96–160	160–256	256–352	>352
CPUEnow	0–50	50–150	150–400	400–1500	

[a] Indicates variables treated as nominal in statistical modelling.

Table 9
OLR prediction of desire for children to inherit the fishing profession (FAM), using origin (TYPE: local or migrant) and ownership (OWNER: boat-owner or crew). The reference is the level of the ordinal or nominal variable taken as a base line.

Predictor	Odds ratio	Lower 95% CI	Higher 95% CI
TYPE*(reference = Locals)*			
Migrant	1.32	0.52	3.32
OWNER*(reference = Boat-owner)*			
Crew	2.08	0.82	5.27

used Gwet's inter-observer reliability statistic, AC1 (Gwet, 2008) (with the R package rel:gac (Martire, 2021)), because AC1 is designed to be immune to the "the paradox of Cohen's kappa" arising from an observer repeating their response (Zec et al., 2017). Gwet's AC1 is a more stable statistic than Kohen's kappa, and less biased when prevalences are asymmetric, though it requires different interpretation (Wongpakaran et al., 2013; Vach and Gerke, 2023).

Appendix C. Statistical results tables

See Tables 9–13.

Table 10
Prediction by OLR of policy ALIGNMENT, from ownership (OWNER), (AGE), (LENGTH) and GEAR (all other variables were non-significant). The reference is the level of the ordinal or nominal variable taken as a base line. (* $p < 0.1$, ** $p < 0.05$).

Predictor	Odds ratio	Lower 95% CI	Higher 95% CI
OWNER*(reference = Boat owner)*			
Crew	0.36**	0.16	0.82
AGE*(reference = 18–25)*			
25–35	0.54	0.16	1.81
35–50	0.69	0.21	2.23
>50	0.36*	0.09	1.42
LENGTH*(reference = 6–8)*			
8–10	0.27**	0.09	0.79
10–12	0.31*	0.10	1.02
>12	0.65	0.04	9.95
GEAR*(reference = Gillnet)*			
Longlines	1.25	0.52	3.01
Multigear	0.55	0.19	1.62

Appendix D. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2024.107406.

Table 11
MLR prediction of SUPPORT in justification for the seasonal closure from fisher's origin (OWNER), gear used (GEAR), catch per trip (CPUEnow), knowledge of the closure (ALIGNMENT). The reference is the level of the ordinal or nominal variable taken as a base line. (Notation: * p < 0.1; ** p < 0.05, *** $p < 0.01$, throughout).

Predictor	Odds ratio	Lower 95% CI	Higher 95% CI
Logit 1: (Yes, but go to lower depth/Yes)			
OWNER*(reference = Boat-owner)*			
Crew	0.18*	0.02	1.61
GEAR*(reference = Gillnet)*			
Longline	9.74**	0.94	101.08
Multigear	58.07**	1.61	2098.4
CPUEnow*(reference = 0–50* kg/trip*)*			
50–150 kg/trip	0.02**	0.00	1.01
150–400 kg/trip	0.21	0.01	4.43
400–1500 kg/trip	0.04*	0.00	1.84
ALIGNMENT*(reference = do not know)*			
Formal procedure	0.07	0.00	
Protect the sea	0.00	0.00	
Spwaning but incorrect	0.55	0.02	15.28
Spwaning season	0.00***	0.00	0.10
Logit 2: (No, fish spawn all year/Yes)			
OWNER*(reference = Boat-owner)*			
Crew	0.17*	0.03	1.11
GEAR*(reference = Gillnet)*			
Longline	9.32**	1.22	71.02
Multigear	45.11***	2.34	869.31
CPUEnow*(reference = 0–50* kg/trip*)*			
50–150 kg/trip	0.09*	0.00	2.05
150–400 kg/trip	0.51	0.03	8.14
400–1500 kg/trip	0.20	0.01	6.01
ALIGNMENT*(reference = do not know)*			
Formal procedure	4.85520E+08	0.00	
Protect the sea	0.06*	0.00	2.10
Spwaning but incorrect	0.37	0.01	14.27
Spwaning season	0.03***	0.00	0.45
Logit 3: (No, fish migrates/Yes)			
OWNER*(reference = Boat-owner)*			
Crew	0.34*	0.07	1.69
GEAR*(reference = Gillnet)*			
Longline	10.97***	2.04	59.05
Multigear	105.34***	7.25	1530.33
CPUEnow*(reference = 0–50* kg/trip*)*			
50–150 kg/trip	0.07**	0.00	0.96
150–400 kg/trip	0.48	0.04	5.20
400–1500 kg/trip	0.01**	0.00	0.35
ALIGNMENT*(reference = do not know)*			
Formal procedure	2.27616E+08	0.00	
Protect the sea	0.01**	0.00	0.52
Spwaning but incorrect	1.96	0.10	39.23
Spwaning season	0.03**	0.00	0.32
Logit 4: (No, it opens earlier than it should/Yes)			
OWNER*(reference = Boat-owner)*			
Crew	0.05**	0.00	0.77
GEAR*(reference = Gillnet)*			
Longline	6.51	0.21	204.17
Multigear	972.18***	17.05	55 430.30
CPUEnow*(reference = 0–50* kg/trip*)*			
50–150 kg/trip	0.01**	0.00	1.05
150–400 kg/trip	0.14	0.00	5.78
400–1500 kg/trip	0.01*	0.00	1.30
ALIGNMENT*(reference = do not know)*			
Formal procedure	0.13	0.00	
Protect the sea	0.00	0.00	
Spwaning but incorrect	0.00	0.00	
Spwaning season	0.02**	0.00	0.51

Table 12
OLR prediction of economic activity during the closure ACTIVITY from fishers' origin (TYPE), age band (AGE) and support for the closure policy (SATISFACTION). The reference is the level of the ordinal or nominal variable taken as a base line.

Predictor	Odds ratio	Lower 95% CI	Higher 95% CI
TYPE*(reference = Locals)*			
Migrant	0.61	0.27	1.36
AGE*(reference = 18–25)*			
25–35	0.46	0.13	1.64
35–50	1.14	0.34	3.88
>50	0.31*	0.07	1.30
SATISFACTION*(reference = a. no, worsens)*			
b. No, recreational boats fish	1.60	0.61	4.18
c. For only one month	10.38***	1.83	58.95
d. Yes	1.33	0.42	4.22

Table 13
OLR prediction of fishers' expectations in ten-years time (FUT) from origin (TYPE), ownership (OWNER), current catch per trip (CPUEnow), support for the closure justification (SUPPORT) and level of SATISFACTION with the policy. The reference is the level of the ordinal or nominal variable taken as a base line.

Predictor	Odds ratio	Lower 95% CI	Higher 95% CI
TYPE*(reference = Locals)*			
Migrant	2.89**	1.11	7.50
OWNER*(reference = Boat-owner)*			
Crew	3.04**	1.13	8.17
CPUEnow*(reference = 0–50* kg/trip*)*			
50–150 kg/trip	2.06	0.42	10.03
150–400 kg/trip	3.38*	0.73	15.73
400–1500 kg/trip	1.72	0.27	11.07
SUPPORT*(reference = "Yes")*			
"No, fish migrate"	0.98	0.25	3.89
"No, fish spawn all year"	2.88	0.55	15.13
"Yes, but escape to depth"	0.08**	0.01	0.99
"Yes, but opens earlier than it should"	0.49	0.05	4.82
SATISFACTION*(reference = "No, worsens")*			
"No, recreational boats fish"	0.39*	0.12	1.28
"Yes, but for only one month"	0.30	0.02	3.71
"Yes"	0.71	0.13	3.90

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