

**Perceptions of trends in Seychelles artisanal trap fisheries:
Comparing catch monitoring, underwater visual census and
fishers' knowledge**

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1 **Perceptions of trends in Seychelles artisanal trap**
2 **fisheries: Comparing catch monitoring, underwater**
3 **visual census and fishers' knowledge**

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14 SUMMARY

15 Fisheries scientists and managers are increasingly engaging with fishers' knowledge
16 (FK) to provide novel information and improve the legitimacy of fisheries
17 governance. Disputes between the perceptions of fishers and scientists can generate
18 conflicts for governance, but can also be a source of new perspectives or
19 understandings. This paper compares artisanal trap fishers' reported current catch
20 rates with landings data and underwater visual census (UVC). Fishers' reports of
21 contemporary 'normal' catch per day tended to be higher than recent median landings
22 records. However, fishers' reports of 'normal' catch per trap were not significantly
23 different from the median CPUE calculated from landings data, and reports of 'good'
24 and 'poor' catch rates were indicative of variability observed in landings data. FK,
25 landings and UVC data all gave different perspectives of trends over a ten-year
26 period. Fishers' perceptions indicated greater declines than statistical models fitted to
27 landings data, while UVC evidence for trends varied between sites and according to
28 the fish assemblage considered. Divergence in trend perceptions may have resulted
29 from differences in the spatial, temporal, or taxonomic focus of each dataset may have
30 been different. Fishers may have experienced and understood behavioural changes
31 and increased fishing power, which may have obscured declines from landings data.
32 Thirdly, Various psychological factors affect memory and recall, and may have
33 affected these memory-based estimates of trends, while different assumptions
34 underlying the analysis of both interview data and conventional scientific data could
35 also have led to qualitatively different trend perceptions. Differing perspectives from
36 these three data sources illustrate both the potential for 'cognitive conflicts' between
37 stakeholders who do not rely on the same data sources, as well as the importance of
38 multiple information sources to understand dynamics of fisheries. We suggest that

39 collaborative investigation of such divergence can facilitate learning and improve
40 fisheries governance.

41 **INTRODUCTION**

42 Widespread interest in fishers' knowledge (FK) for fisheries science and management
43 (Haggan et al. 2007) derives from two main perspectives. Firstly, FK is thought to
44 contain useful information to improve the performance of fisheries management
45 (Jentoft et al. 1998; Haggan and Neis 2007). FK may encompass a finer spatial
46 resolution and be more up to date than formal scientific knowledge (Rochet et al
47 2008). FK often also provides a longer historical perspective than other data sources
48 (Dulvy and Polunin 2004; Ames 2007; Lavides et al 2009), especially in tropical reef
49 fisheries (Johannes 1998) and has broader scope. For example FK may include
50 information on ecological, social, technical and economic aspects of fisheries that
51 have historically been neglected by conventional fisheries science (Moller et al.
52 2004). Secondly, the process of co-management (Jentoft et al. 1998) relies on the
53 development of institutions that facilitate knowledge exchange between stakeholders,
54 scientists and managers to develop greater understanding and more efficient
55 governance (Hoefnagel et al. 2006).

56

57 Fishers and scientists commonly have diverging perceptions of resources and may be
58 suspicious of the reliability of one another's perceptions (Gray et al 2008, Hall-Arber
59 2003), creating barriers for integrating knowledge sources and conflicts in multi-
60 stakeholder arenas. Adams et al. (2003) suggest that such 'cognitive conflicts' may be
61 the main challenge in managing common pool natural resources, while Ostrom et al.
62 (1999) identify shared understandings, one of the factors that can support collective
63 action to sustain resources. However, investigating discrepancies between scientific

64 and fishers' perceptions may also provide opportunities for expansion and revision of
65 scientific knowledge (Johannes and Neis 2007).

66

67 Many possible explanations exist for disagreement between scientists' and fishers'
68 perceptions. Disputes often focus on the validity of either perception and the question
69 of which is correct. Scientists may be sceptical when fishers dispute the severity of
70 stock declines (termed the 'you-would-say-that' issue by Daw 2008). Indeed, political
71 conflicts or vested interests can incentivise fishers to bias their stated views either
72 consciously or unconsciously (Harmon-Jones and Harmon-Jones 2007). However,
73 numerous examples exist in which fishers' disputes of scientific findings have been
74 shown to be based on more than strategic self interest (Haggan and Neis 2007).

75

76 Disputes can arise simply because they are based on observations of different parts of
77 the fisheries system. FK has been shown to vary according to the social context of
78 fishers (Crona and Bodin 2006) or by the types of gear used (Gerhardinger et al.
79 2006). Fishers and scientists may perceive the system at different scales (Berkes
80 2006), or through monitoring different variables (Verweij et al 2010). Inaccuracies or
81 biases can also affect both scientific and fishers' perceptions, due to the context in
82 which perceptions are formed.

83

84 Human perceptions are affected by psychological recall processes (Tversky and
85 Kahneman 1973), existing beliefs and behaviours (Balcetis and Dunning 2007) and
86 frameworks of understanding (Miller 2000; Fazey et al. 2006). Perception of trends
87 over time requires the recall, and comparison of current and former conditions, while
88 taking account of variation to distinguish long-term trends from short-term noise (van

89 Densen 2001). The act of recalling past conditions is accomplished by a variety of
90 cognitive heuristics (Tversky and Kahneman 1974). For example, the ‘availability
91 heuristic’ is used when estimating the frequency of an event based on the ease with
92 which it is recalled. As such, more available memories, which may be pleasant,
93 unusual or emotive for the individual (Matlin 2004), will appear to be more frequent,
94 and have a greater influence on the perception of past conditions. The ‘shifting
95 baseline syndrome’ has also been reported to affect fishers perceptions of
96 deteriorating environmental conditions (Saenz-Arroyo et al. 2005; Bunce et al. 2007)
97 and can operate at a societal level, as a result of younger generations being unaware of
98 past abundance (termed generational amnesia); or as a result of individuals forgetting
99 previous abundances (termed personal amnesia) (Papworth et al. 2009).

100

101 The process of researching and recording FK has been characterised by Holm (2003)
102 as the construction of a decontextualised knowledge he refers to as FEK*. This useful
103 distinction between *in situ* FK, and FEK* as the product of FK research, highlights
104 inaccuracies or biases which may exist as artefacts of the process of generating FEK*.
105 Recording FK can be affected by political or vested interests of individuals, fisheries
106 management regimes, and methodological aspects of the research (Maurstad 2000;
107 Davis and Wagner 2003)

108

109 Scientific data are also subject to potential inaccuracies due to poor resolution, biases,
110 and incorrect assumptions, and fisheries science is well known to be subject to a range
111 of uncertainties (Charles 1998) and even the political and social context in which it is
112 generated (Finlayson 1994). Fisheries-dependent data collection can be biased by
113 misreporting, poor sampling design and effort (over emphases on certain landing sites

114 or gears) and changes in gear use and targeting behaviour by fishers in response to
115 various socioeconomic drivers (de Mutsert et al. 2008). In many fisheries, effort is not
116 monitored, or the resolution is low, while subtle changes in efficiency are difficult to
117 monitor. For example, fishers can introduce or improve fishing technology (e.g. GPS,
118 fish-finders), change the targeting of fish or increase distance travelled, trap soak
119 times or effort exerted during fishing (Jennings et al. 2001). Such changes are almost
120 impossible to record and standardise (Hilborn and Walters 1992). Interviews with
121 fishers have the advantage of being able to investigate such changes (e.g. Neis et al.
122 1999, Quirijns et al 2008, Eigaard 2009). In multispecies tropical fisheries, data
123 collection is often aggregated at high taxonomic levels and large spatial scales.
124 Underwater visual census (UVC) offers detailed fisheries-independent data, but biases
125 in UVC may arise from spatial extent of sampling, habitat structure and fish
126 behaviour (Edgar et al. 2004) and the method can normally only sample a limited
127 proportion of the available habitat.

128

129 Moving beyond the ‘who-is-right’ mode of understanding disputes between FK and
130 science becomes possible with the appreciation that *all* types of knowledge are partial
131 and affected by the context in which they are created (Murray et al 2008). Disputes
132 may provide opportunities to expand the scope of knowledge available for resource
133 management, and to revise scientific understandings, which may be based on too
134 narrow a conception of the system (Hoffmann-Riem and Wynne 2002).

135

136 This paper examines how perceptions of resource abundance in the artisanal trap
137 fishery Seychelles differ according to fisher interviews and two common forms of
138 scientific fisheries data: UVC by scientific divers, and landings surveys conducted by

139 fieldworkers. We compare the perceptions of catch, catch-per-unit-effort (CPUE),
140 variance in catches, and abundance trends over a 10-year period.

141

142 **METHODS**

143 **Study sites**

144 Artisanal trap fisheries of the inner Seychelles islands provide a rare opportunity
145 among tropical artisanal fisheries of a long (10+ year) time span of catch and effort
146 data, and UVC data on fish density and biomass.

147

148 The fishery is conducted from small boats with outboard engines of 15-40 hp, and
149 uses three types of traditional bamboo traps. *Kasye peze* and *Kasye dormi* are both
150 sturdily constructed and left for a soak time of up to 3 days. *Kasye peze* are unbaited
151 and wedged amongst corals on the shallow reef flats, while *Kasye dormi* are set
152 outside the reef crest in depths of up to 60m and may be baited (Daw 2008). *Kasye*
153 *lavol* have a lighter construction, are baited, and are placed in a variety of depths for
154 of several hours. Siganids, lethrinids and scarids are the most important families
155 caught in traps but *kasye dormi* also catch substantial quantities of mullids and
156 lutjanids. Octopus, labrids, acanthurids, serranids, haemulids, balistids, muraenids and
157 pomacanthids are also fished while chaetodontids and scorpaenids are frequently
158 caught but discarded. *Kasye lavol* are used to target known spawning aggregations of
159 *Siganus sutor* in which case they catch this species almost exclusively (Robinson et
160 al. 2004).

161

162 Trap-caught fish are used for local consumption and are typically sold by fishers
163 themselves, in ‘packets’, of several fish tied together. The price of packets tends to be
164 constant but their weight and species composition can vary according to catches.

165

166 Three areas of Seychelles were chosen for this study to correspond with existing UVC
167 data collection sites (Jennings et al. 1995; Figure 1). The dominant trap type and
168 season were selected in each to maximise the relationship between the data types
169 (Table 1).

170

171 [Figure 1]

172 [Table 1]

173

174 **Data collection**

175 *Perceptions of fishers*

176 Individual, structured interviews were conducted from September to November 2005
177 focussed on the dominant trap type used in each area (Table 1). In each area a list of
178 trap fishers was compiled from landing site visits and speaking to fishers, local
179 residents, and Seychelles Fishing Authority (SFA) staff. All fishers that could be
180 contacted were approached for interview. Individual trap fishers were asked about
181 their typical catch and effort on a ‘good’, ‘poor’ and ‘normal’ day; their perception of
182 trends over the past ten years (or since the start of their career if less than ten years);
183 their typical catch and effort ten years previously; and several indicators of changes in
184 effective effort (length of vessel, engine power, days fished per week, maximum
185 depth fished, maximum distance travelled from landing site to fishing ground and trap

186 soak time) currently and ten years previously (or since the start of their career if less
187 than ten years). These formed part of an interview which also included understandings
188 of fish stock dynamics and opinions on fisheries management adapted from Walmsley
189 et al (2005)(see Supplementary online material). Catches were generally reported in
190 packets, while effort was described by the number of trap hauls per day. Mean CPUE
191 was calculated by dividing the day's catch by the number of trap hauls. To ensure
192 standardised data within each area, and maximum overlap with the UVC data, fishers
193 were only included in the analysis if they answered questions on the dominant trap
194 type in each region, and spent all of their fishing time within the regions shown in
195 Figure 1.

196

197 *Catch assessment survey data*

198 Landings data were extracted from the SFA artisanal fisheries catch assessment
199 survey (CAS), a stratified catch and effort monitoring system that has been in place
200 since 1985. Fieldworker effort is randomly distributed between 63 landing sites on
201 Mahé, Praslin and La Digue, within site strata that are defined according to the
202 number and type of boats active at the sites. Fieldworkers record fishing activities
203 (number and types of vessels fishing and number of trips and gears, by type, used)
204 and landings are estimated from counts of the number of fish or packets, sample
205 weights, and estimated percentage taxonomic composition of catches (Mees 1990).

206

207 The CAS distinguishes 'active traps' (*kasye lavol*) from 'fixed traps', but not between
208 the two types of fixed traps (*kasye peze* and *kasye dormi*). Interviews with trap
209 fishermen indicated that *kasye dormi* were predominantly used in W Mahé and that
210 there is typically a seasonal pattern in the use of fixed traps in E Mahé, with *kasye*

211 *dormi* being used in the calmer NW monsoon and at least 75% of fishers exclusively
212 using *kasye peze* inside the reef during the rougher SE monsoon. Thus, to maximise
213 the overlap between interview data on *kasye peze*, landings from fixed traps during
214 the SE monsoon (June-September) were selected. Records for fixed traps and active
215 traps from W Mahé and SW Praslin were taken from all months assuming that they
216 represented *kasye dormi* and *kasye lavol* respectively. The few landings records from
217 vessels without outboard engines were excluded, as all interviewees used outboard
218 engines. Mean CPUE was calculated by dividing daily catch by the gear number. A
219 number of data (0.5-10% depending on area) were excluded as the number of gears
220 had apparently been entered erroneously as one, inflating estimates of CPUE.

221

222 *Underwater visual census*

223 Fisheries-independent indications of trends in fish biomass were obtained from
224 underwater visual census (UVC) conducted in 1994 and 2005. Three sites,
225 representing carbonate reef, granitic reef and patch reef habitats, were surveyed
226 within each of the 3 areas (Figure 1). At each site, 16 replicate 7m-radius point-count
227 surveys of reef fishes were conducted. The abundance and size of 134 species of
228 diurnally-active reef-associated fish were recorded at each count (Jennings et al. 1995;
229 Graham et al. 2006). Length calibration was achieved by estimating the lengths of a
230 random assortment of lengths of PVC pipe before each day's sampling, until the
231 observer was within an error range of 1cm; mean errors for 1994 and 2005 were 3.1%
232 and 2.2%, respectively (Graham et al. 2007). Abundance-length data were converted
233 to biomass using published length-weight relationships (Letourneur et al. 1998;
234 Froese and Pauly 2006).

235

236 **Data Analysis**237 *Catches as reported by fishers*

238 Most fishermen reported catches in numbers of packets. To allow comparison with
239 landings data, packet numbers were converted to kg based on a sample of 239 original
240 SFA fieldworker datasheets detailing weights of individual packets from July to
241 December 1996 and from July 2004 until June 2005. Packets were significantly larger
242 in 2004 ($p < 0.001$). Accordingly, estimates of current and past (ten years previous)
243 catches from fisher interviews were converted by multiplying number of packets by
244 3.63 kg and 2.94 kg, respectively.

245

246 *Contemporary catch and CPUE*

247 For an indication of 'current' catches, a subset of landings data was taken for a three-
248 year period prior to the interviews in order to provide enough data ($n = 75-150$), to
249 indicate the frequency distribution and central tendency of catches in each area. To
250 capture variability in catches, records representing the aggregate catch of more than
251 one boat (~10% of records) were removed. Frequency distributions of catch and
252 CPUE were plotted for each area. Due to the positively skewed nature of the landings
253 data and the existence of outliers, median rather than mean values were chosen to
254 compare with fishers' perception of a 'normal' days catch and CPUE.

255

256 For each interviewed fisher, the difference between median landings records, and
257 their reported 'normal' catch and catch per trap (dCatch and dCPUE), was calculated
258 as a proportion of median landings values:

259

260 Proportional catch difference ($dCatch_{fa}$) = $(NC_{fa} - M_a)/M_a$

261

262 Where: NC_f is a normal day's catch in fishery a according to fisher f, and M_a is the
263 median catch from landings data in fishery a.

264

265 For each fishery, the distribution of $dCatch$ and $dCPUE$ was tested for significant
266 differences from zero (Wilcoxon signed ranks non-parametric test) to indicate
267 whether reports of normal catches by fishers, differed from median catches according
268 to CAS data.

269

270 *Time trends as perceived by catch assessment survey*

271 For analysis of trends in landings data, records from between January 1995 and July
272 2005 were selected from the CAS database. Average catch per day and average catch
273 per trap (CPUE) were analysed for trends. Visual assessment of data showed different
274 trends between the three main landing sites in the SW Praslin area, so only data from
275 Grande Anse (where the majority of interviews were conducted) were included.

276

277 The presence of linear or non-linear trends in each time series was assessed by
278 comparing generalised additive models (GAMs) fitted to each dataset using the gam
279 function from the mgcv package in R. GAMs allow the visualisation of non-linear
280 relationships between dependent and multiple explanatory variables (Zuur et al.
281 2007). Seasonality in catches was accounted for by the inclusion of a month smoother
282 term in all models except those for the E. Mahé *Kasye peze* fishery, which only
283 included the four months of the NE monsoon. Three alternative models were fit to the
284 data from each area representing: no trend over time (month smoother term only), a

285 linear trend over time (month smoother and year linear terms) and a non-linear trend
286 over time (month and year smoother terms).

287

288 The degree to which each model fitted the data was assessed using Aikike's
289 Information Criterion (AIC). Models explaining the greatest proportion of variance
290 with fewest parameters were indicated by the lowest AIC (Burnham and Anderson
291 2002). Δ AIC was calculated, as the difference between each model and the best of the
292 three models. Residual plots and graphical outputs of the GAM smoother term were
293 examined. Autocorrelation between years was not accounted for, possibly leading to
294 over estimation of the degree of fit, particularly for GAMs.

295

296 Where AIC scores indicated a linear trend with year (where the linear trend was
297 favoured over the no-trend model, the modelled change was presented as annual
298 change as a percent of interpolated year 2000 values (change/year/yr2000). Graphical
299 representations of the year smoother from the non-linear trend were plotted and an
300 indication of recent trends was provided by presenting the slope of the GAM between
301 the last 2 years as a % of the ten-year mean.

302 *Time trends as perceived by underwater visual census*

303 Total UVC-measured fish biomass, and biomass of target species (Table S1,
304 Supplementary materials) that were large enough (>6cm body depth) to be caught by
305 the inshore trap fishery (Graham et al. 2007), were analysed for differences between
306 1995 and 2005. Linear models with year, site (see Figure 1) and site \times year interaction
307 were fitted for each area, to square-root-transformed data to reduce the influence of
308 outliers. Models were selected for each area by AIC-based stepwise removal of terms
309 (Zuur et al. 2007) and the difference between years was indicated by the significance

310 of the year term. If site \times year interactions were retained in the model selection
311 (suggesting a different trend at each site), trends were reported for each site. Where
312 variances were unequal between years, Welch's t-tests, which do not assume equal
313 variance, were used to test for a difference between years. All detected differences
314 were converted to change/year/yr2000.

315 *Time trends as perceived by fishers*

316 Qualitative indicators of fishers' perceptions of trends were taken as the proportions
317 of fishers who perceived a decline, no change or an increase at each site. Quantitative
318 indicators of trends were also calculated for each fisher as the difference between
319 reported contemporary catches and catches ten years previously (or at the start of their
320 trap fishing activities if they had fished for less than 10 years). Only data from fishers
321 with eight or more years of experience were used for quantitative trends. Six different
322 quantitative trend indices were calculated as a result of using two different reports of
323 current catches ('normal' and 'good' catches); and of using three different units to
324 indicate catch: total daily catch, daily catch per trap in kg, and daily catch per trap in
325 the units used by interviewees (usually packets). Each of these trends were presented
326 as change/year/yr2000.

327 *Indicators of effective effort*

328 Fishers who had been fishing for at least five years were included in the analysis of
329 indicators of effort efficiency. The proportion of interviewees who had increased,
330 decreased or not changed with regards to each indicator was calculated and the
331 percentage change from initial levels for each fisher was calculated. Changes for the
332 sample were calculated in terms of mean percentage change and mean absolute
333 change (e.g. miles).

334

335 **RESULTS**336 **Perceptions of current catches from interviews and landings**

337 Landings data from all three fisheries showed a typical positively-skewed distribution
338 of catches with extreme values at the higher end of the range (Figure 2). The
339 proportional difference between a fishers' normal catch and the median catch for that
340 fishery (dCatch) was significantly greater than zero for all three fisheries (Table 2)
341 indicating that most fishers' reports of a 'normal' catch (converted to kg) were greater
342 than the median of landings. Fishers reports tended to have greater extremes than
343 landings; five of the 30 interviewees reported 'normal' catches that exceeded the 95%
344 quantiles of landings data. 'Poor' catches were frequently lower than the 5% quantile
345 of landings, and 'good' catches higher than the 95% quantile, particularly in E Mahé.
346 Overall, one third of reported 'poor' catches involved nothing being caught, but only
347 two of the 362 landings records involved no catch, both from Praslin.

348

349 [Figure 2]

350 [Table 2]

351

352 When converted to CPUE, fishers' reports showed more agreement with landings
353 data. Reports of 'normal' CPUE in E Mahé and SW Praslin straddled the median
354 landing (Figure 2) and dCPUE was not significantly different from zero (Table 2).
355 dCPUE in W Mahé was lower than dCatch but still generally positive and
356 significantly different from 0 at 10% level. The 95% quantile of CPUE tended to be
357 straddled by reports of 'good' CPUE (Figure 2).

358

359 Extreme reported values were apparent in each fishery, especially for catch. Half of
360 the ‘good’ catch reports in E Mahé lay outside the range of the landings data, while
361 one ‘normal’ report in W Mahé was similar to maximum recorded landings. However,
362 expressing reported data as CPUE tended to reduce the occurrence and extent of
363 extreme values. For example, catch reports included three ‘normal’ and 11 ‘good’
364 values which were larger than the maximum recorded landing, whereas for CPUE,
365 only one ‘normal’ and two ‘good’ reports extended beyond maximum landings. Two
366 SW Praslin reports of ‘good’ catches were two and three times greater than the
367 maximum recorded landings, but were comparable to typical landings when presented
368 as CPUE as they came from three hauls of a large number (ten) of traps.

369

370 **Time trends according to catch assessment survey**

371 Model selection indicated different trends in the 3 fisheries and in the case of E Mahé,
372 between catch and CPUE (Table 3). Highly significant year terms for W Mahé catch
373 and CPUE and E Mahé CPUE (but not catch) were also reflected in lower AICc
374 values for linear than null models. All linear trends were positive, and equivalent to 2-
375 15% change/year/yr2000. SW Praslin showed no evidence of any long term trend in
376 CPUE, but a trend in catch was indicated by a marginally significant year term in the
377 linear model, which was selected by AIC over the null model.

378

379 [Table 3]

380

381 The GAMs were selected by AIC in all cases. Graphical representations of the GAM
382 smoother terms gave an indication of the underlying trend in catches by year when

383 seasonal trends are accounted for by the month term in the models (Table 3). All sites
384 show some evidence of declines over the last two years, ranging from 9% of mean
385 values in W Mahé CPUE to 37% in E Mahé CPUE.

386

387 **Time trends according to fishers' perceptions**

388 Most fishers (82%, n=28) in all areas perceived that catches had declined (Table 4),
389 but quantitative indices of trends gave different conclusions depending on which
390 index was used (Figure 3). Most fishers cited 'normal' catches that were less than
391 previous catches (representing declines of up to 15%/year/yr2000), but roughly half of
392 fishers' 'good' catches were greater than previous catches. In terms of the different
393 indices, daily catch suggested less of a decline than catch per trap, and catch per trap
394 converted to kg indicated less severe declines than catch per trap in the fishers' own
395 units, due to the different packet conversion for current and former times. 'Good'
396 versus previous catch in kg (Figure 3, top right), indicated no decline on average,
397 while 'normal' versus former catch per trap in the fishers own units (Figure 3, lower
398 left) suggested the most pessimistic picture, in which only 1 fisher (from E Mahé)
399 perceived an increase in catches and 13 perceived a decrease of up to 17%
400 /year/yr2000.

401

402 [Table 4]

403 [Figure 3]

404

405 Time trends according to UVC data

406 UVC data from 1994 and 2005 in E Mahé indicated declines in total fish biomass but
407 not in biomass of trap fish (Welch $t=2.05$, $p=0.04$) (Table 4). There was a significant
408 site \times year interaction at W Mahé so the three sites were tested separately. Total
409 biomass was significantly less in 2005 at the patch reef site (Welch $t=4.87$, $p<0.001$),
410 but not at the other sites, while trap fish biomass was significantly lower at all sites
411 ($F=4.98$, $p=0.028$), and much lower in 2005 at the patch reef site (Welch $t=3.60$,
412 $p=0.001$). No significant trends were detected in SW Praslin.

413

414 Comparisons of trend perceptions in the datasets

415 Qualitatively, 10-year trend indications from the three sources of information were
416 very different. Fisher interviews indicated declines in all areas, UVC from some sites
417 indicated declines and landings data showed increases over the ten years. Landings
418 did, however, indicate a decline in catches over the final one to three years of the time
419 series. When comparing between areas, W Mahé landings data showed the strongest
420 evidence for an increase, the least severe decline according to fisher interviews, but
421 the most evidence for a decline according to UVC. Meanwhile SW Praslin showed no
422 evidence for a decline according to UVC, but had the most pessimistic quantitative
423 indications from fishers.

424

425 Trends in fishing behaviour

426 For most behavioural indicators, the majority of fishers did not report changes, but
427 more fishers reported increases in effort than decreases (Figure 4). The only exception

428 was 'days fished per week' which had decreased for 14% (n=29) fishers and increased
429 for only 3%. Vessel fishing power had commonly increased, with 45% (n=22) of
430 fishers having upgraded to larger engines (nine fishers), or obtained engines for the
431 first time (two fishers), and 41% of fishers fishing in larger vessels. 31% and 44%
432 (n=16) of the fishers had increased the number of traps fished and soak time,
433 respectively, with an average increase of ~25% in each. A minority of fishers had
434 increased the depth or distance at which they fished, with an average extension of 1.4
435 nm in their range.

436

437 **DISCUSSION**

438 In this study we compared perceptions of artisanal trap catches and CPUE as obtained
439 from fisher interviews and structured landings surveys; and perceptions of trends over
440 ten years according to interviews, landings surveys and UVC. Landings data indicated
441 lower catch per day, but similar catch per trap to fishers' stated 'poor', 'normal' and
442 'good' catches both in terms of the central tendency of the data (median CPUE and
443 'normal' catch per trap), and the range of the data indicated by the frequency
444 distributions and the fishers' reports of 'poor' and 'good' catches. Indications of
445 trends over 10 years however, differed widely, with fisher interviews indicating
446 declines, landings data indicating no trends or increases, and UVC indicating no
447 trends or a decline depending on the site and fraction of the fish community sampled.

448

449 **Contemporary catch indications from landings and fisher interviews**

450 The observed congruence between contemporary CPUE according to landings and
451 catch per trap according to interviews is encouraging for situations in which time and
452 resources are not available to initiate a structured landings recording programme. For

453 Seychelles trap fisheries, it seems that if effort is carefully accounted for, a reasonable
454 account of both the magnitude and the variability of *contemporary* catch per trap can
455 be obtained from interviews with fishers (e.g. Lunn and Dearden 2006). However,
456 similar studies over a larger range of fisheries are needed to investigate the generality
457 of this finding.

458

459 Our findings emphasise the importance of detailed measurement of fishing effort.
460 Catch per day gave a different and less compatible result than the more detailed catch
461 per trap, because of variations in the quantity of traps used (2-14) and hauls made per
462 day (1-3) by fishers. Extreme reports of high daily catches may have created suspicion
463 of exaggeration by interviewees, but when the data were presented in terms of catch
464 per trap, individuals' answers fell comfortably within the range of the rest of the
465 sample.

466

467 Answers to interview questions can be affected by how interviewees interpret the
468 context and wording of questions (Schwarz 1999). For example, a 'normal' catch may
469 have been cited based on a range of catch experiences, which may include or exclude
470 zero catches, or be focussed on particular seasons or areas. Different cognitive
471 heuristics may have been used to construct an answer, such as stating the first trip that
472 is recalled from memory, calculating the desired catch to cover costs and make an
473 acceptable profit, or attempting some form of averaging over the range of a number of
474 recalled trips. To encourage respondents to use a similar anchoring-and-adjustment
475 heuristic (Tversky and Kahneman 1974), and to remove some variability due to
476 fishers placing more or less emphasis on particularly good catches, we asked about
477 'good', 'poor' and then 'normal' catches. While not eliminating problems of question

478 interpretation, this provided a more standardised measurement of the perception of
479 current catches and also provided some indication of catch variability. Variability is in
480 itself of interest as it affects fishers' power to perceive spatial or temporal trends in
481 catches (Oostenbrugge et al. 2001; Pet-Soede et al. 2001; van Densen 2001), has
482 implications for livelihoods and vulnerability, and it has been shown to rise in
483 response to increasing fishing pressure (McClanahan et al. 2008), potentially
484 indicating loss of fish stock resilience (Hsieh et al. 2006). More generally, variance
485 indicators have been proposed as predictors of ecological regime-shifts (Carpenter
486 and Brock 2006).

487

488 **Perception of trends from UVC and fisher interviews**

489 Trends perceived from fishers' and UVC data were not in accord, which can be
490 attributed to many factors affecting the two data sources, and the limited overlap
491 between UVC and the fishery in terms of depths, habitats and species. *Kasye peze*
492 fishers tend to fish shallower than the reef slopes targeted by UVC, while *Kasye*
493 *dormi* fishers can expand beyond the shallow fringing reefs targeted by UVC onto the
494 expansive Mahé plateau. Graham et al (2007) estimated that only 50-60% of trap
495 fishing grounds overlapped with habitats and depths sampled by these UVC data.

496

497 Filtering of the UVC data for 'trap fish' changed indications from 'decline' to 'no
498 detectable decline' in E Mahé, and vice versa in W Mahé. Trends in W Mahé were
499 different at the different sites, with severe declines indicated on the patch reef habitat.
500 This illustrates the complexity of comparing independent indicators of fish biomass
501 over a complex heterogeneous seascape and the potentially critical impact of choices
502 of how to select and interpret scientific data for the trends perceived in a resource. If

503 the patch-reef site was representative of areas targeted by trap fishers, this analysis
504 would predict the perceptions of declines reported by fishers.

505

506 **Perception of trends from landings data and fisher interviews**

507 The importance of effort is again highlighted by different trends indicated by catch
508 and CPUE from landings (Table 3). Figure 4 indicates an increase in some
509 individuals' effective effort through increasing vessel power and soak times. This may
510 account for discrepancy between landings and fishers' perceptions. Fishers may have
511 perceived resource declines, while compensating for them by increasing effective
512 effort. Such declines cannot be perceived from landings without detailed information
513 on changes in fishing behaviour/technology and the spatial distribution of effort.
514 Effective effort can also be reduced by a range of factors, including management
515 regulations, fuel prices, or at a personal level due to ageing, or deterioration of gear or
516 vessels.

517

518 Although several fishers reported poor catches of zero, CAS data had few zero
519 catches. This may be due to fishers with zero catches returning directly to
520 mooring/anchorage sites instead of the monitored landing sites, fishers avoiding
521 interviews with fieldworkers on zero-catch days, or fieldworkers preferentially
522 sampling and interviewing fishers with landings over those without. For fisheries in
523 which zero catches are common, the failure to record them may introduce biases in
524 mean or raised estimates from landings data.

525

526 The implications of cognitive processes of memory and recall have been scarcely
527 studied in FK literature. This study allows consideration of how they may affect

528 perceptions of resource trends. For example, the time window of ten years may have
529 contributed to the difference in perception of CPUE trends from fisher interviews and
530 CAS data. All six of the GAM smoother terms showed a decline in recent years
531 (although caution should be taken with the interpretation of the ends of GAM
532 smoothers, A. Zurr pers comm.). Fishers answering questions about a ten-year time
533 trend may have answered with regards to recent trends which are more available to
534 memory, even if they were questioned about trends over 10 years.

535

536 Similar to most artisanal fisheries in the World (Berkes et al. 2001), catches from the
537 Seychelles trap fishery are sold for profit. Changes in the gross revenue or profits
538 from fishing may therefore be of greater importance to the fisher, and thus better
539 remembered, than changes in quantity of catch (Matlin 2004). Increasing costs and/or
540 decreasing fish prices could result in perceptions of a decline as profitability fell. In
541 Seychelles, fishers' profitability may have been negatively affected by
542 macroeconomic difficulties that worsened over the study period, making imported
543 equipment increasingly expensive; or decreasing unit fish prices (as indicated by the
544 increasing trend in packet size identified over the ten years). More generally,
545 fluctuations in fuel prices, global market prices and government subsidies for fishers
546 may affect perceptions of trends in resource abundance.

547

548 The availability heuristic (Tversky and Kahneman 1974) would predict that
549 particularly large or unusual catches would dominate the perception of former
550 catches. In the left-hand panels of Figure 3, 'normal' catches are compared against
551 reported former catches (assuming them also to be normal). If these reported former
552 catches do in fact refer to memorably good catches, then fishers would perceive more

553 severe declines creating a ‘memory illusion’, in which declining trends are
554 exaggerated or incorrectly perceived (Papworth et al. 2009). Memory illusion operates
555 in the opposite direction to the ‘shifting-baseline syndrome’ in which severity of
556 declines is underestimated (Saenz-Arroyo et al. 2005; Bunce et al. 2007). Such
557 potential biases arising from recall remain a challenge for the use of memory-based
558 perceptions of trends, in the absence of records or repeated surveys. Biases are
559 expected to increase with the length of time over which interviewees are asked to
560 remember. Further research is required to investigate the magnitude, and impact of
561 these biases on trend perception. Cognitive science can be used to understand the
562 processes, but to specifically understand them in fisheries, empirical research is
563 needed to compare memory-based verbal reports of catches with independent records
564 of the same individual’s actual catches, in different contexts.

565
566 In conducting FK research and creating FEK*, FK is filtered and adjusted through
567 decisions, methods and assumptions of the researchers. The significant impacts of
568 such assumptions are emphasised by comparing the left and right hand panels of
569 Figure 3. Assuming that reports of former catches were representative of memorably
570 ‘good’ catches, and thus comparing them with contemporary ‘good’ catches (right-
571 hand panels of Figure 3) would give less of an indication of declines. Different
572 inferences are also generated depending on the way in which catch estimates from
573 fishers were processed. In this case, trends according to figures converted to kg were
574 more severe than trends calculated from fishers’ own units, and CPUE trends were
575 more severe than catch trends (Figure 3) due to the increasing trap number. This
576 shows the critical impact of how FK is processed and analysed for deriving

577 conclusions. By changing the assumption of how to interpret fishers' reports, the
578 nature of the perceived trend is qualitatively changed.

579

580 Conflicts between scientific, or bureaucratic, perspectives on resources and those of
581 resource users are common in fisheries (Gray et al. 2008). In this case, fishers had
582 more pessimistic perceptions of catch trends than scientific data, but in spite of this,
583 fishers were not supportive of introducing effort or catch controls, or limiting entry to
584 the fishery (Daw 2008). Thus, it is important to note that perceptions and knowledge
585 are not the sole factors determining personal environmental behaviour (Kollmuss and
586 Agyeman 2002), and preferences for potential management measures are complicated
587 by a range of political factors, values, personal interests and power relations.

588

589 **CONCLUSION**

590 All three data sources gave different perceptions of trends in the biomass of fish and
591 catches over the study period. Fishers' experience of the fishery could have resulted in
592 more pessimistic perceptions because of a) increasing numbers of traps and other
593 increases in effective effort, b) an emphasis on recent catch declines, c) psychological
594 biases in the recall of past catches or d) the increasing weight of fish packets
595 effectively reducing the price of fish. Meanwhile, landings data may have perceived
596 positive trends due to a) monitoring of catch by kg rather than packets, b) a long 10-
597 year perspective, without emphasis on recent trends, c) failure to record zero catches
598 and d) an inability to account for increasing efficiency. In addition, the trends implied
599 by each dataset can be qualitatively affected by changing underlying assumptions
600 about the types of fish measured by UVC or the meaning of fishers' reports of
601 previous catches. This illustrates the critical impact of how both FK and scientific

602 data are processed and analysed on the resultant conclusions. This paper has
603 documented changes in effective effort, different trends identified over different
604 timescales, habitats or species, changes in fish price, and the existence of zero
605 catches. Cognitive processes affecting trend perception are potentially very
606 significant, but are not measured or documented in this study and require further
607 research.

608

609 An increasingly prevalent perspective suggests the importance of combining multiple
610 information sources for monitoring and learning about social-ecological systems like
611 fisheries (Folke et al. 2003). Fishers may be able to perceive trends more rapidly and
612 locally that are masked from landings data by subtle increases in fishing effort or
613 efficiency or aggregation over large-scales (Neis et al. 1999, Rochet et al. 2008),
614 while landings data may have more statistical power to observe large-scale trends by
615 integrating the catches of many different fishers (van Densen 2001). UVC may be
616 able to monitor actual changes in biomass of fish regardless of variability and change
617 in catchability and fisher behaviour, but may have poor coverage or limited temporal,
618 spatial, depth or taxonomic overlap with exploited fish populations. Neither scientific
619 nor fishers' perceptions can be considered to provide the 'true' picture of the resource,
620 as they are partial in terms of spatial or taxonomic coverage, or the variables
621 considered, and contextually contingent in terms of the methodology, and social-
622 economic environment in which they are created. Consideration of various
623 perceptions increases the awareness of the contingent nature of each, enables conflicts
624 to be identified and addressed, and helps to avoid over-confidence in one signal.
625 Over-confidence in signals from trawler CPUE contributed to the overfishing and
626 collapse of the Northern cod (Finlayson 1994; Neis 1997). Further research should

627 involve fishers and scientists in examining the reasons why perceptions are divergent
628 to improve understandings of trends in the fishery and to investigate issues such as
629 how changes in effective effort influence the different perspectives. Stock
630 assessments supported by various types of fishers' knowledge are needed to provide a
631 reliable and accepted status of the resource. Such processes also help to address
632 'cognitive conflicts' and facilitate social learning, which is thought to be important for
633 co-management (Armitage et al. 2008).

634

635 In the case of the Seychelles artisanal trap fishery, new initiatives have recently been
636 instigated to establish fisher-organisations and co-management, which may provide a
637 medium for such collaborative learning. This research suggests that participatory
638 research and monitoring to address diverging perceptions and understandings will be
639 a key process supporting this initiative. In terms of specific recommendations, the
640 scales of monitoring in co-management should be aligned with those over which
641 fishers perceive the resource and the participatory development of indicator systems
642 may provide a more intuitive and acceptable scientific approach to monitoring and
643 setting management targets.

644

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655

Proof for Review

656 **References**

- 657 Adams, W. M., D. Brockington, J. Dyson and B. Vira (2003) Managing Tragedies:
 658 Understanding Conflict over Common Pool Resources. *Science* **302**(5652): 1915-
 659 1916.
- 660 Ames, T. (2007) Putting fishers' knowledge to work: Reconstructing the Gulf of
 661 Maine cos spawning grounds on the basis of local ecological knowledge. *In Fishers'*
 662 *Knowledge in Fisheries Science and Management*. N. Haggan, B. Neis and I. G.
 663 Baird, Eds. Paris, UNESCO. p 353-363.
- 664 Armitage, D. R., R. Plummer, F. Berkes, R. I. Arthur, A. T. Charles, I. J. Davidson-
 665 Hunt, A. P. Diduck, N. C. Doubleday, D. S. Johnson, M. Marschke, P. McConney, E.
 666 W. Pinkerton and E. K. Wollenberg (2009) Adaptive co-management for social-
 667 ecological complexity. *Frontiers in Ecology and the Environment*. 7(2): 95-102.
- 668 Balcetis, E. and D. Dunning (2007) Cognitive dissonance and the perception of
 669 natural environments. *Psychological Science* **18**(10): 917-921.
- 670 Berkes, F. (2006) From community-based resource management to complex systems:
 671 The scale issue and marine commons. *Ecology and Society* **11**(1).
- 672 Berkes, F., R. Mahon, P. McConney, R. Pollnac and R. Pomeroy (2001) *Managing*
 673 *Small-scale Fisheries: Alternative Directions and Methods*. Ottawa, International
 674 Development Research Centre.
- 675 Bunce, M., L. D. Rodwell, R. Gibb and L. Mee (2007) Shifting Baselines in Fishers'
 676 Perceptions of Island Reef Fishery Degradation. *Ocean and Coastal Management*.
 677 **51**(4): 285-302.
- 678 Burnham, K. P. and D. R. Anderson (2002) *Model selection and multimodel*
 679 *inference: a practical information-theoretic approach*. New York, Springer-Verlag.

- 680 Carpenter, S. R. and W. A. Brock (2006) Rising variance: a leading indicator or
681 ecological transition. *Ecology Letters* **9**: 311-318.
- 682 Charles, A. T. (1998) Living with uncertainty in fisheries: analytical methods,
683 management priorities and the Canadian groundfishery experience. *Fisheries*
684 *Research* **37**: 37-50.
- 685 Crona, B. and O. Bodin (2006) What you know is who you know? Communication
686 patterns among resource users as a prerequisite for co-management. *Ecology and*
687 *Society* **11**(2).
- 688 Davis, A. and J. R. Wagner (2003) Who knows? On the importance of identifying
689 "Experts" when researching local ecological knowledge. *Human Ecology* **31**(3): 463-
690 489.
- 691 Daw, T. M. (2008) *How Fishers Count: Engaging Fishers' Knowledge in Fisheries*
692 *Science and Management*. PhD. School of Marine Science & Technology, and School
693 of Geography, Politics & Sociology. Newcastle upon Tyne, Newcastle University
694 www.tinyurl.com/tdaw-thesis.
- 695 Dulvy, N. K. and N. V. C. Polunin (2004) Using informal knowledge to infer human-
696 induced rarity of a conspicuous reef fish. *Animal Conservation* **7**: 365-374.
- 697 Edgar, G. J., N. S. Barrett and A. J. Morton (2004) Biases associated with the use of
698 underwater visual census techniques to quantify the density and size-structure of fish
699 populations. *Journal of Experimental Marine Biology and Ecology* **308**(2): 269-290.
- 700 Eigaard, O.R. (2009) A bottom-up approach to technological development and its
701 management implications in a commercial fishery. *ICES J. Mar. Sci.*, **66**: 916-927.
- 702 FAO (2005) *Putting into practice the ecosystem approach to fisheries*. Rome, Food
703 and Agriculture Organisation of the United Nations, 76 pp.

- 704 Fazey, I., J. A. Fazey, J. G. Salisbury, D. B. Lindenmayer and S. Dovers (2006) The
705 nature and role of experiential knowledge for environmental conservation.
706 *Environmental Conservation* **33**(1): 1-10.
- 707 Finlayson, A. C. (1994) *Fishing for Truth: A Sociological Analysis of Northern Cod*
708 *Stock Assessments from 1977 to 1990*. St Johns, ISER.
- 709 Folke, C., J. Colding and F. Berkes (2003) Chapter 14. Synthesis. *In Navigating*
710 *Social-Ecological Systems: Building Resilience for Complexity and Change*. F.
711 Berkes, J. Colding and C. Folke, Eds. Cambridge, Cambridge University Press. p 1-
712 29.
- 713 Gerhardinger, L. C., R. C. Marenzi, A. A. Bertoncini, R. P. Medeiros and M. Hostim-
714 Silva (2006) Local ecological knowledge on the goliath grouper *Epinephelus itajara*
715 (Teliostei: Serranidae) in southern Brazil. *Neotropical Ichthyology* **4**(4): 441-450.
- 716 Graham, N. A. J., S. K. Wilson, S. Jennings, N. V. C. Polunin, J. P. Bijoux and J.
717 Robinson (2006) Dynamic fragility of oceanic coral reef ecosystems. *Proceedings of*
718 *the National Academy of Sciences of the United States of America* **103**(22): 8425-
719 8429.
- 720 Graham, N. A. J., S. K. Wilson, S. Jennings, N. V. C. Polunin, J. Robinson, J. P.
721 Bijoux and T. M. Daw (2007) Lag effects in the impacts of mass coral bleaching on
722 coral reef fish, fisheries and ecosystems. *Conservation biology* **21**(5): 1291-1300.
- 723 Gray, T., J. Hatchard, T. Daw and S. M. Stead (2008) New cod war of words: 'cod is
724 God' versus 'sod the cod' - two opposed discourses on the North Sea Cod Recovery
725 Programme. *Fisheries Research* **93**(1-2): 1-7.
- 726 Haggan, N. and B. Neis (2007) The changing face of fisheries science and
727 management. *In Fishers' Knowledge in Fisheries Science and Management*. N.
728 Haggan, B. Neis and I. G. Baird, Eds. Paris, UNESCO. p 421-432.

- 729 Haggan, N., B. Neis and I. G. Baird (2007) *Fishers' Knowledge in Fisheries Science*
730 *and Management*. Paris, UNESCO. 437 pp.
- 731 Hall-Arber, M. (2003) It's pretty fishy... *Maritime Studies* **2**(1): 42-44.
- 732 Harmon-Jones, E. and C. Harmon-Jones (2007) Cognitive dissonance theory after 50
733 years of development. *Zeitschrift für Sozialpsychologie*, **38**: 7-16.
- 734 Hilborn, R. and C. J. Walters (1992) *Quantitative fisheries stock assessment. Choice,*
735 *Dynamics and Uncertainty*. New York, Chapman and Hall. 570 pp.
- 736 Hoefnagel, E., A. Burnett and D. C. Wilson (2006) Chapter 4. The Knowledge base of
737 co-management. *In The Knowledge Base for Fisheries Management*. L. Motos and D.
738 C. Wilson, Eds. Amsterdam, Elsevier. p 85-108.
- 739 Hoffmann-Riem, H. and B. Wynne (2002) In risk assessment, one has to admit
740 ignorance - Explaining there are things we can't know could improve public
741 confidence in science. *Nature*, **416**: 123-123.
- 742 Holm, P. (2003) Crossing the border: On the relationship between science and
743 fishermen's knowledge in a resource management context. *Maritime Studies*, **2**: 5-33.
- 744 Hsieh, C. H., C. S. Reiss, J. R. Hunter, J. R. Beddington, R. M. May and G. Sugihara
745 (2006) Fishing elevates variability in the abundance of exploited species. *Nature*
746 **443**(7113): 859-862.
- 747 Jennings, S., E. M. Grandcourt and N. V. C. Polunin (1995) The effects of fishing on
748 the diversity, biomass and trophic structure of Seychelles' reef fish communities.
749 *Coral Reefs* **14**: 225-235.
- 750 Jennings, S., M. J. Kaiser and J. D. Reynolds (2001) *Marine Fisheries Ecology*.
751 Malden, Blackwell. 417 pp.
- 752 Jentoft, S., B. J. McCay and D. C. Wilson (1998) Social theory and fisheries co-
753 management. *Marine Policy* **22**(4-5): 423-436.

- 754 Johannes, R. E. (1998) The case for data-less marine resource management: examples
755 from tropical nearshore finfisheries. *Trends in Ecology and Evolution* **13**(6): 243-245.
- 756 Johannes, R. E. and B. Neis (2007) The value of anecdote. In *Fishers' Knowledge in*
757 *Fisheries Science and Management*. N. Haggan, B. Neis and I. G. Baird, Eds. Paris,
758 UNESCO. p 41-58.
- 759 Kollmuss, A. and J. Agyeman (2002) Mind the gap: why do people act
760 environmentally and what are the barriers to pro-environmental behavior?
761 *Environmental Education Research* **8**(3): 239-260.
- 762 Lavides, M. N., N. V. C. Polunin, S. M. Stead, D. G. Tabaranza, M. T. Comeros and
763 J. R. Dongallo (2009) Finfish Disappearances Around Bohol, Philippines Inferred
764 from Traditional Ecological Knowledge. *Environmental Conservation*, **36**, 235-244.
- 765 Lunn, K. E. and P. Dearden (2006) Monitoring small-scale marine fisheries: An
766 example from Thailand's Ko Chang archipelago. *Fisheries Research* **77**: 60-70.
- 767 Matlin, M. W. (2004) *Cognition*. Hoboken, Wiley.
- 768 Maurstad, A. (2000) Trapped in biology: An interdisciplinary attempt to integrate fish
769 harvesters' knowledge into Norwegian fisheries management. In *Finding Our Sea*
770 *Legs: Linking Fishery People and Their Knowledge with Science and Management*. B.
771 Neis and L. Felt, Eds. St. Johns, ISER. p 135-152.
- 772 McClanahan, T. R., C. C. Hicks and E. S. Darling (2008) Malthusian overfishing and
773 efforts to overcome it on Kenyan coral reefs. *Ecological Applications* **18**(6): 1516-
774 1529.
- 775 Mees, C. C. (1990) *Seychelles artisanal catch assessment survey: notes for*
776 *implementation*. Victoria, Seychelles Fishing Authority, 39 pp.
- 777 Miller, C. A. (2000) The Dynamics of Framing Environmental Values and Policy:
778 Four Models of Societal Processes. *Environmental Values* **9**: 211-233.

- 779 Moller, H., F. Berkes, P. O. B. Lyver and M. Kislalioglu (2004) Combining science
780 and traditional ecological knowledge: monitoring populations for co-management.
781 *Ecology and Society* **9**(3): 2.
- 782 de Mutsert, K., J. H. Cowan, T. E. Essington and R. Hilborn (2008) Reanalyses of
783 Gulf of Mexico fisheries data: Landings can be misleading in assessments of fisheries
784 and fisheries ecosystems. *Proceedings of the National Academy of Sciences* **105**(7):
785 2740-2744.
- 786 Neis, B. (1997) Fishers' ecological knowledge and stock assessment in Newfoundland.
787 *In How deep is the Ocean? Historical Essays on Canada's Atlantic Fishery*. J. E.
788 Candow and C. Corbin, Eds. Sydney, Nova Scotia, University College of Cape Breton
789 Press. p 243-260.
- 790 Neis, B., D. C. Schneider, L. Felt, R. L. Haedrich, J. Fischer and J. A. Hutchings
791 (1999) Fisheries assessment: what can be learned from interviewing resource users?
792 *Canadian Journal of Fisheries and Aquatic Sciences* **56**(10): 1949-1963.
- 793 Oostenbrugge, J. A. E., W. L. T. Densen and M. A. M. Machiels (2001) Risk aversion
794 in allocating fishing effort in a highly uncertain coastal fishery for pelagic fish,
795 Moluccas, Indonesia. *Canadian Journal of Fisheries and Aquatic Sciences* **58**(8):
796 1683-1691.
- 797 Ostrom, E., J. Burger, C. B. Field, R. B. Norgaard and D. Policansky (1999)
798 Revisiting the commons: Local lessons, Global Challenges. *Science* **284**: 278-282.
- 799 Papworth, S. K., J. Rist, L. Coad and E. J. Milner-Gulland (2009) Evidence for
800 shifting baseline syndrome in conservation. *Conservation Letters* **2**(2): 93-100.
- 801 Pet-Soede, C., W. L. T. Van Densen, J. G. Hiddink, S. Kuyl and M. A. M. Machiels
802 (2001) Can fishermen allocate their fishing effort in space and time on the basis of

- 803 their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia.
804 *Fisheries Management and Ecology* **8**(1): 15-36.
- 805 Quirijns, F.J., J.J. Poos and A.D. Rijnsdorp (2008) Standardizing commercial cpue
806 data in monitoring stock dynamics: accounting for targeting behaviour in mixed
807 fisheries. *Fisheries Research*, **89**: 1–8.
- 808 Rochet, M-J., Prigent, M., Bertrand, J. A., Carpentier, A., Coppin, F., Delpech, J-P.,
809 Fontenelle, G., Foucher, E., Mahé, K., Rostiaux, E., and Trenkel, V. M. 2008.
810 Ecosystem trends: evidence for agreement between fishers' perceptions and scientific
811 information. *ICES Journal of Marine Science*, **65**: 1057–1068.
- 812 Robinson, J., M. Isidore, M. A. Marguerite, M. C. Öhman and R. J. Payet (2004)
813 Spatial and temporal distribution of reef fish spawning aggregations in the Seychelles
814 - An interview-based survey of artisanal fishers. *Western Indian Ocean Journal of*
815 *Marine Science* **3**: 63-69.
- 816 Saenz-Arroyo, A., C. M. Roberts, J. Torre, M. Carino-Olvera and R. R. Enriquez-
817 Andrade (2005) Rapidly shifting environmental baselines among fishers of the Gulf
818 of California. *Proceedings of the Royal Society B-Biological Sciences* **272**(1575):
819 1957-1962.
- 820 Schwarz, N. (1999) Self-reports: How questions shape the answers. *American*
821 *Psychologist* **54**(2): 93-105.
- 822 Tversky, A. and D. Kahneman (1973) Availability: A heuristic for judging frequency
823 and probability. *Cognitive Psychology* **5**: 207-232.
- 824 Tversky, A. and D. Kahneman (1974) Judgment under uncertainty: Heuristics and
825 biases. *Science* **185**: 1124-1131.

- 826 van Densen, W. L. T. (2001) *On the Perception of Time Trends in Resource Outcome.*
827 *Its importance in fisheries co-management, agriculture and whaling. PhD Thesis.*
828 Enschede, the Netherlands, Twente University. 299 pp.
- 829 Walmsley, S., C. Howard and P. Medley (2005) *Participatory Fisheries Stock*
830 *Assessment (ParFish): Guidelines.* London, MRAG. 166 pp.
- 831 Verweij, M.C., W.L.T. van Densen, and A.J.P. Mol (2010) The tower of Babel:
832 Different perceptions and controversies on change and status of North Sea fish stocks
833 in multi-stakeholder settings. *Marine Policy* **34**(3): 522-533.
- 834 Zuur, A. F., E. N. Ieno and G. M. Smith (2007) *Analysing Ecological Data.* New
835 York, Springer-Verlag. 672 pp.

836 **Figure Legends**

837 Figure 1. Seychelles study locations. Dark lines indicate the 3 areas of coastline where
838 interviews were conducted. Shapes indicate underwater visual census sites in three
839 different habitats (filled circles = coral, open circles = granite, triangles = patch reefs).
840 Areas for the catch assessment survey are identified by capital letters (AAP = Anse
841 Aux Pins, AB = Anse Boileau, AR = Anse Royale, AK = Anse Kerlan, GA = Grande
842 Anse, PG = Port Glaud, SP = South Praslin), adapted from Jennings et al. (1995)

843

844 Figure 2. Frequency distributions of daily catches and catch per unit effort from three
845 different Seychelles trap fisheries from landings data (upper panels) and individual
846 reports of catch and CPUE from fisher interviews (lower panels, circles = 'normal'
847 day, triangles = 'poor' day, squares = 'good' day) lower panels show a 'strip chart' in
848 which each fisher is represented by a different y axis value. Thick vertical lines
849 indicate median and dotted vertical lines indicate 5 and 95% quantiles of landings
850 data.

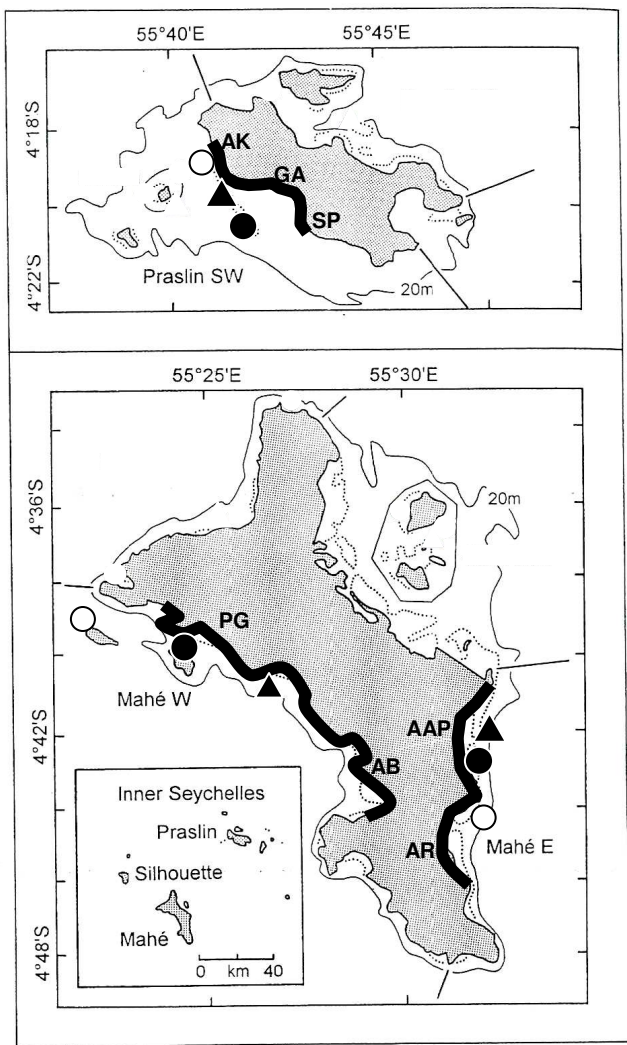
851

852 Figure 3. Quantitative indicators of changes in catch from trap fisher interviews in
853 three trap fisheries, calculated by comparing past catches with either 'normal' (left
854 panel) or 'good' (right panel) reported catches; and calculated in three different catch
855 units (daily catch converted to kg, CPUE converted to kg/trap and CPUE in original
856 reported units/trap). Asterisks indicate mean values. Vertical lines indicate zero
857 change. Circles = East Mahé *kasye peze*, Triangles = West Mahé *Kasye dormi*,
858 Crosses = Southwest Praslin *Kasye lavol*. Darker shading indicates more severe
859 declines are indicated.

860

861 Figure 4. Changes in quantitative indicators of fishing effective effort by trap fishing
862 interviewees during the previous 5-10 years. Mean changes are reported firstly in
863 absolute terms and then as a percentage. Bars indicate the proportion of the
864 interviewees whose indicators had increased, stayed the same or decreased. Days per
865 week refers to days spent fishing. Soak Time refers to time between setting and lifting
866 traps, Max Depth refers to depth of water in which traps were set, Max Range refers
867 to the maximum distance travelled to fishing grounds. * percentage changes in
868 distance and engine power are not displayed due to low or zero initial values.

Figure 1



Review

Figure 2

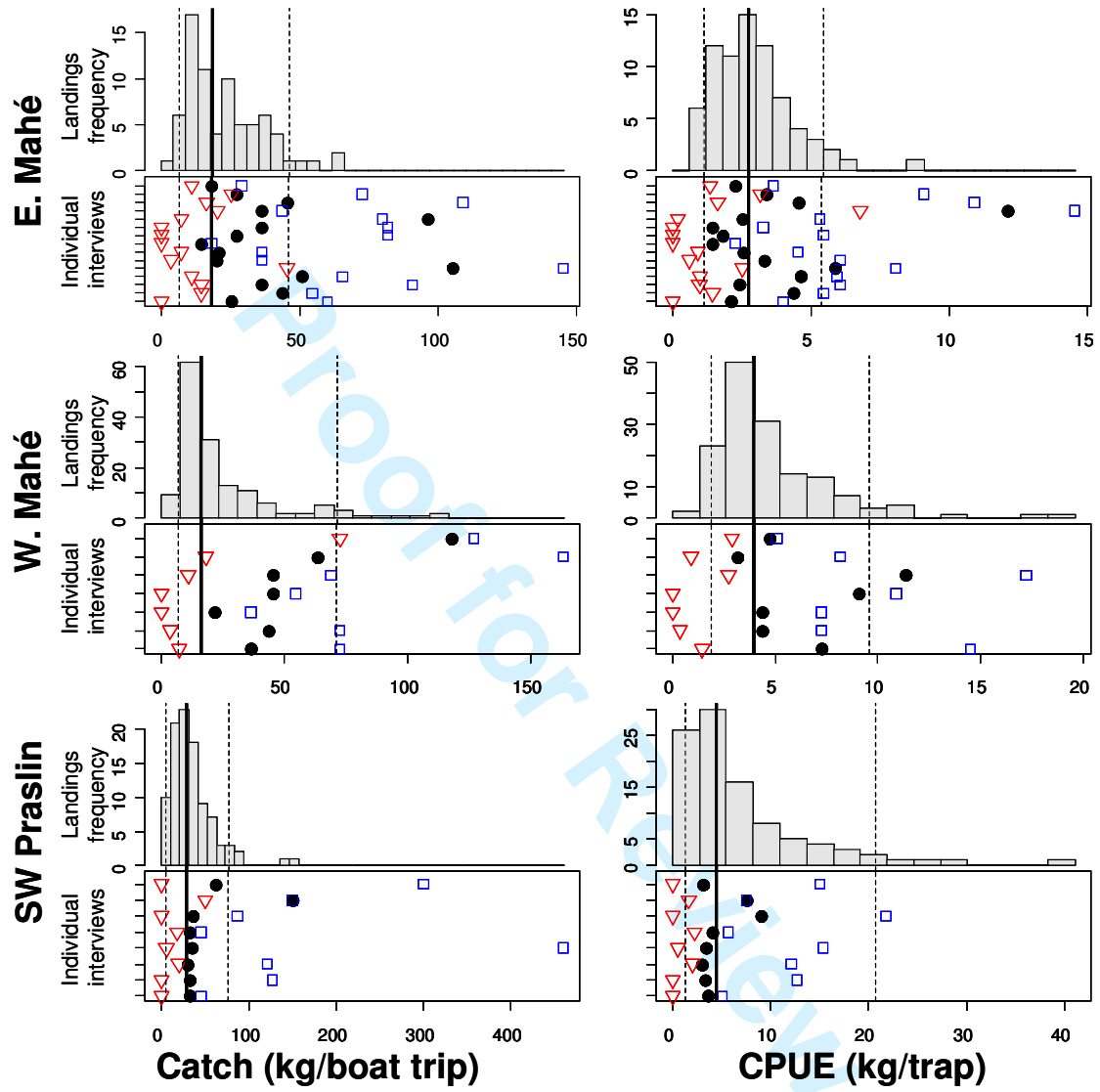


Figure 3

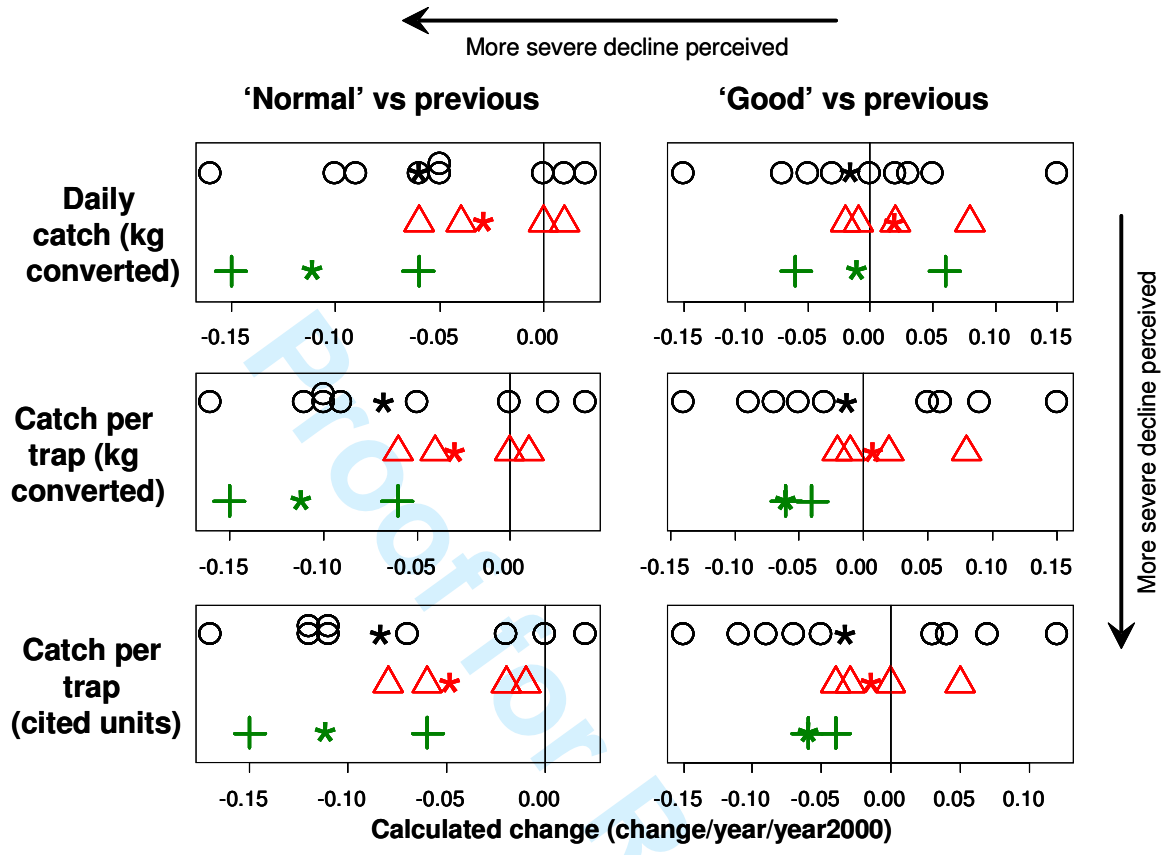
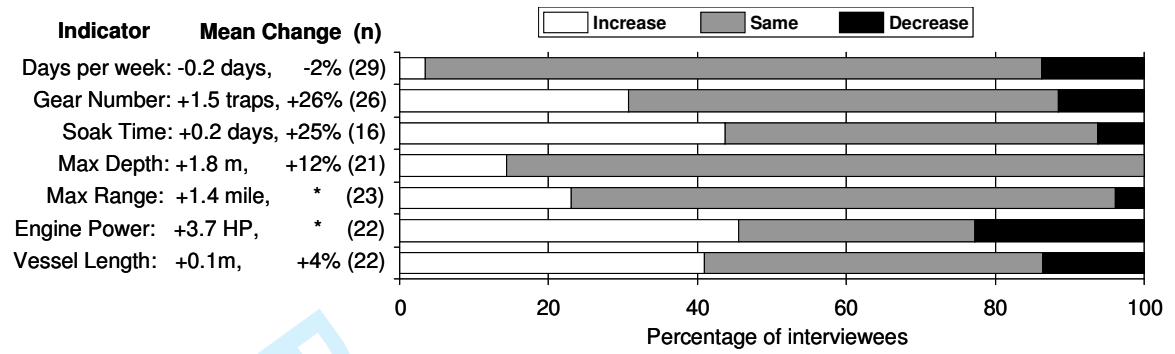


Figure 4



Proof for Review

1 Table 1. The area and trap type distinctions used to define the 3 fisheries selected for
 2 this study with the total number of fishers identified, interviewed and who refused to
 3 be interviewed.

4

Area	Gear	Number of trap fishers					# of landings records	
		Identified	Interviewed	Refusals	Valid area/gear ²	Valid trends ³	Recent catches	10 yr trend
E Mahé	<i>Kasye peze</i>	35	23	5	15	11	74 ¹	401 ¹
W Mahé	<i>Kasye dormi</i>	10	8	0	7	5	150	312
SW Praslin	<i>Kasye lavol</i>	16	9	4	8	2	100	719 ⁴

5 ¹ Records from June to September only

6 ² Fishers who fished with the specified gears within the area of the UVC surveys and landings data

7 ³ Fishers with ≥ 8 years of continuous gear use

8 ⁴ Records from Grand Anse only

9

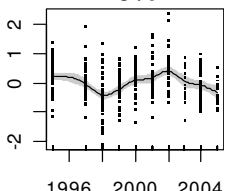
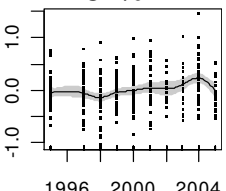
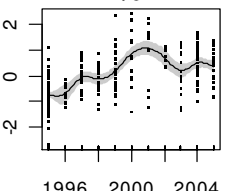
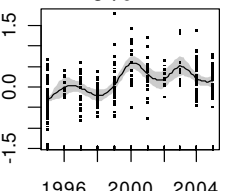
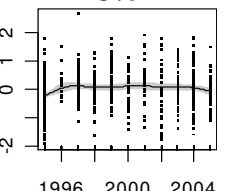
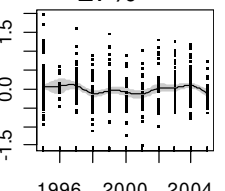
10 Table 2. Results of Wilcoxon signed rank tests (with estimated median values) of
 11 dCatch and dCPUE (differences between 'normal' catches and CPUE reported by
 12 fishers and median landings).

13
 14

Fishery	N	dCatch			dCPUE		
		Median	V	P	Median	V	P
E Mahé <i>kasye peze</i>	15	0.998	115	<0.001***	-0.058	77	0.352
W Mahé <i>kasye dormi</i>	7	1.80	28	0.016*	0.195	24	0.094
SW Praslin <i>kasye lavol</i>	8	0.160	36	0.001**	-0.201	15	0.742

15

Table 3. Selection of candidate models for catch and CPUE of each fishery and indicators of trends where present. Shaded cells indicate the lowest (i.e. best) AIC between the linear models. Smooth terms are plotted with partial residuals (shaded areas correspond to 2 standard errors above and below the estimate of the smooth).

		<i>Area and gear</i>					
		E Mahé Kasye Peze		W Mahé Kasye Dormi		SWP Kasye Lavol	
		Catch	CPUE	Catch	CPUE	Catch	CPUE
Model selection (Δ AIC values)	Null model: $y \sim s(\text{month})$	59.2	20.2	162.3	104.1	15.5	13.4
	Linear trend: $y \sim \text{year} + s(\text{month})$	61.2	7.1	62.6	45.0	12.3	14.9
	Non-linear trend: $y \sim s(\text{year}) + s(\text{month})$	0	0	0	0	0	0
10 yr Linear trend	Linear effect indicated? (significance of year term)	No	Yes ($p=0.000$)	Yes ($p=0.000$)	Yes ($p=0.000$)	Yes ($p=0.024$)	No
	Modelled change (/10years)		+ 0.91 kg	+ 26.8 kg	+ 2.7 kg	+ 2.4 kg	
	Slope (/year/yr2000)		+ 3.5%	+ 14.7%	+ 7.8%	+ 1.9%	
GAM	Deviations from mean (% of mean)	+51% to -37%	+34% to -20%	+111% to -69%	+64% to -49%	+8% to -26%	14% to -16%
	'04-'05 slope (% of mean)	-21.6%	-37%	-17%	-9%	-13%	-27%
	Smooth term (log scale on y axis)						

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Table 4. Perceptions of trends from UVC and fisher interviews in each fishery.

		<i>Area and gear</i>					
		E Mahé Kasye Peze		W Mahé Kasye Dormi		SWP Kasye Lavol	
Fishes included		All fish	Trap fish	All fish	Trap fish	All fish	Trap fish
UVC	Trend detected (/year/yr2000)¹	- 1.6%	No trend	No trend (coral and granite sites) - 6.3% (patch reef site)	- 1.6% overall (- 7.4% at patch reef site)	No trend	No trend
	Perceived trends²						
Fishers' Perceptions	No quant. estimates	9		4		2	
	Change from previous to 'normal' CPUE (/year/yr2000)¹	- 6.1 % (SD=6.7%)		- 2.3 % (SD = 3.3%)		- 10.5 % (SD = 6.3%)	
	Change from previous to 'good' catch (/year/yr2000)¹	- 0.3 % (SD=9.5%)		+ 1.7 % (SD = 4.5%)		- 0.5 % (SD = 1.4%)	

¹ Proportional changes are calculated as annual change as a percentage of the modelled value for year 2000.

² Shaded bars indicate responses based on 8-10 years experience open bars indicate other timespans (9 with 3-7 years and one with 30 years due to leaving and returning to fishing)

Online Supplementary material for “**Perceptions of trends in Seychelles artisanal trap fisheries: Comparing catch monitoring, underwater visual census and fishers’ knowledge**”

TIM M. DAW, JAN ROBINSON AND NICHOLAS A. J. GRAHAM

Table S1 - Species selected as trap target species and the cut-off length for inclusion as 'trap fish'

Family	Species	Depth/Fork Length	Fork length at 6cm body depth (cm)
Haemulidae	<i>Diagramma pictum</i>	0.33	18.3
Haemulidae	<i>Plectorhinchus orientalis</i>	0.29	20.8
Labridae	<i>Cheilinus fasciatus</i>	0.32	19
Lethrinidae	<i>Lethrinus lentjan</i>	0.36	16.7
Lethrinidae	<i>Lethrinus mahsena</i>	0.38	15.9
Lethrinidae	<i>Lethrinus nebulosus</i>	0.35	17.2
Lethrinidae	<i>Lethrinus obsoletus</i>	0.33	18.3
Lethrinidae	<i>Lethrinus olivaceus</i>	0.29	20.8
Lethrinidae	<i>Lethrinus rubrioperculatus</i>	0.26	23.3
Lutjanidae	<i>Aprion virescens</i>	0.24	25.5
Lutjanidae	<i>Lutjanus bohar</i>	0.32	18.9
Lutjanidae	<i>Lutjanus fulviflamma</i>	0.3	20.2
Lutjanidae	<i>Lutjanus gibbus</i>	0.37	16.2
Lutjanidae	<i>Lutjanus kasmira</i>	0.32	18.5
Mullidae	<i>Parupeneus barberinus</i>	0.27	21.9
Mullidae	<i>Parupeneus bifasciatus</i>	0.29	20.9
Nemipteridae	<i>Scolopsis frenatus</i>	0.29	20.7
Pomacanthidae	<i>Apolemichthys trimaculatus</i>	0.55	10.9
Pomacanthidae	<i>Pomacanthus imperator</i>	0.5	12.1
Scaridae	<i>Cetoscarus bicolour</i>	0.35	17.3
Scaridae	<i>Chlorurus atrilunula</i>	0.33	18.4
Scaridae	<i>Chlorurus sordidus</i>	0.31	19.2
Scaridae	<i>Scarus falcipinnis</i>	0.35	17.4
Scaridae	<i>Scarus ghobban</i>	0.36	16.7
Scaridae	<i>Scarus rubroviolaceus</i>	0.32	18.7
Serranidae	<i>Aethaloperca rogaa</i>	0.35	17.3
Serranidae	<i>Anyperodon leucogramma</i>	0.25	24.2
Serranidae	<i>Cephalopholis argus</i>	0.29	20.9
Serranidae	<i>Cephalopholis leopardus</i>	0.3	20.1
Serranidae	<i>Cephalopholis miniata</i>	0.28	21.4
Serranidae	<i>Epinephelus fasciatus</i>	0.27	22.3
Serranidae	<i>Epinephelus spilotoceps</i>	0.25	24.2
Siganidae	<i>Siganus argenteus</i>	0.33	18.1
Siganidae	<i>Siganus puelloides</i>	0.37	16.4
Siganidae	<i>Siganus sutor</i>	0.39	15.4

Example interview guide from E. Mahe (adapted from Walmsley et al)

Rec Entered

SampleID:

ParFish Trap Interview

Background information:

Fisher Name		Date	
Port		Interviewer	
Community		Location	
Skipper <input type="checkbox"/> Boat owner <input type="checkbox"/> Diver <input type="checkbox"/> Snorkeller <input type="checkbox"/> FT/PT/Not Fishing			

All questions should be related to the coastal areas of Mahe only and catches in Kasye Dormi or Peze unless the interviewee only uses Kasye la vol

Effort:

Question	Answer	Comments / Notes
For how many years have you been trap fishing here?		
What kind of traps did you use in coastal Mahe in this last year?	Dormi Peser La Vol	
How many days per week did you lift traps here last year?	VN: VS:	
How many traps do you lift per day here?	VN: VS:	
Longest/shortest soak time?		
Vessel Description:		
Vessel type		
Length:		
Engine type and power:		
Nav equipment:	ES <input type="checkbox"/> GPS <input type="checkbox"/>	
Fishing Grounds: Normal fishing grounds?	VN	
<i>Get as detailed as possible information for coastal sites</i>	VS	
Maximum distance to grounds?		
Minimum distance to grounds?		
Deepest traps		
Shallowest traps		
What habitats do you put your traps on?		
Trap materials		
Bait used		
PAST (aim for 10 years)		
Time delay?		
What kind of traps did you use in coastal Mahe 10 years ago?	Dormi Peser La Vol	
How many days per week did you lift	VN:	

traps here ten years ago?	VS:	
How many traps did you lift per day here? 10 years ago	VN:	
	VS:	
Soak time 10 years ago		
Vessel Description 10 years ago:		
Vessel type		
Length:		
Engine type and power:		
Nav equipment:	ES <input type="checkbox"/> GPS <input type="checkbox"/>	
Fishing Grounds:		
Normal fishing grounds 10 years ago? <i>Get as detailed as possible information for coastal sites</i>		
Maximum distance to grounds 10 years ago?		
Minimum distance to grounds 10 years ago?		
Deepest traps 10 years ago		
Shallowest traps 10 years ago		
Trap materials 10 years ago		
Bait used 10 years ago		

Perceptions of resource, and catch rates

Question	Answer	Comments / Notes
Resource condition perception Do you think population of fish you catch are in a good state?		
Trends in catch rate: Over the last 10 years, are you catching more, less or the same amount of fish per trap?		
Why do you think this is the case?		

Type and location of traps for yield questions:							
Current Max catch rate: Now, on the best days, how many packets do you catch? How many traps do you use?	No:						
	Traps:						
Current Min catch rate: Now, on the worst days, how many packets do you catch? How many traps do you use?	No:						
	Traps:						
Current Normal catch rate: Normally, how many packets do you catch in a day? How many traps do you use?	No:						
	Traps:						
Current target spp: Which species do you catch mostly now? (If you have 10 packets how many would be each type?)							
Former Normal catch rate: 10 years ago, Normally how many packets did you catch? With how many traps did you used to use?	No:						
	Traps:						

Former target spp: Have the types of fish you catch changed over the last 10 years? (If you had 10 packets how many would be each type?)						

Hypothetical Questions

Question	Answer	Comments / Notes						
Catch rate for unexploited stock: Imagine a place never fished or which has been left for a long time without fishing, what is the most and least number of packets you could catch? How many traps would you use?	<table border="1"> <tr> <td rowspan="2">Min</td> <td>No:</td> </tr> <tr> <td>Traps:</td> </tr> <tr> <td rowspan="2">Max</td> <td>No:</td> </tr> <tr> <td>Traps:</td> </tr> </table>	Min	No:	Traps:	Max	No:	Traps:	
Min	No:							
	Traps:							
Max	No:							
	Traps:							
How did you come up with this answer?								
Recovery time: If no-one fished on your grounds, how long do you think it would take for the stocks to recover so that it was like that? How did you come up with this answer?	Immigr. <input type="checkbox"/> Growth <input type="checkbox"/> Reprod. <input type="checkbox"/>	Time unit						

Level of Effort

Question	Answer	Comments / Notes						
If more fishers used kasye here do you think you would catch less?								
If some of the other fishermen stopped using kasye would you catch more?								
Do you think the amount of fishing (no traps) for the size of the resource is OK? How many traps should there be? Why do you think that?	<table border="1"> <tr> <td>Could be greater</td> <td></td> </tr> <tr> <td>Just right</td> <td></td> </tr> <tr> <td>Too much</td> <td></td> </tr> </table>	Could be greater		Just right		Too much		
Could be greater								
Just right								
Too much								

Trends in individual species

Species changes Are there any species which have changed particularly since 10 years ago?		
---	--	--

Species Cards

- I am only interested in populations of fish in the coastal areas around Mahe/Praslin
- This list is not exhaustive, many (e.g. bordomar) are not pictured
- Some pictures show fish which are not found in Seychelles
- I am interested in changes which have occurred over the past 10 years

Card nos.	Name	Often /Rare	Many /few	Abund. ↑→↓	Size ↑→↓	Notes
group						

<i>Card nos.</i>	<i>Name</i>	<i>Often /Rare</i>	<i>Many /few</i>	<i>Abund.</i> ↑→↓	<i>Size</i> ↑→↓	<i>Notes</i>
<i>Group</i>						

<i>Group</i>						

<i>Group</i>						

General trends (if groups have not already been covered)

<i>Group</i>	<i>Often /Rare</i>	<i>Many /few</i>	<i>Abund.</i> ↑→↓	<i>Notes</i>
<i>Bourzwa</i>				
<i>All other red snapper</i>				
<i>Vyey makonde</i>				

Structural knowledge and Management opinions

<p>Factors affecting stocks</p> <p>What things control/affect the population of the fish you catch? (Ask open Q then prompt)</p> <p>How does this affect fish?</p>	Trap fishing	V Y N	
	Other Fishing	V Y N	
	Predation	V Y N	
	Food	V Y N	
	Habitat quality	V Y N	
	Reclamation	V Y N	
	Recruitment	V Y N	
	Immigration	V Y N	
	Tsunami	V Y N	
	Coral Bleaching	V Y N	
	Other	V Y N	
Of these, which is the most important?			
<p>Management Opinions:</p> <p>What do you think should/needs to be done to manage the kasye fishery</p> <p>How much/when/How?</p>	Limited licences	V Y N	
	Closed season	V Y N	
	Closed area	V Y N	
	Mesh size	V Y N	
	Others	V Y N	

Information sources and overview

<p>Apart from your own experience, How do you get information about the state of kasye fish stocks?</p>	
<p>Do you see catches from other kasye fishers? How? How many? From where?</p>	
<p>Do you think SFA have a good idea about the state of stocks and the kasye fishery?</p> <p>Do you know what they think/know?</p> <p>Do you agree?</p>	

Personal Information:

Question	Answer	Comments / Notes
How old are you?		
How many years of formal education did you do?		
Ownership of gears		
Do you own the boat you use?		
Do you own your kasye?		
Do you have any loans to pay on fishing vessel/equipment?		
Fisher importance – Dependents:		
Including you, how many people rely on your income?		

<p>Other income Other than kasye fishing. What other fisheries or work do you have for income?</p>		
<p>Fisher importance - Dependence on fishing: What proportion of your income comes from kasye fishing?</p>		
<p>Future aspirations Do you want to continue Kasye fishing? Will you still be using Kasye in 10 years time?</p>		

Who else fishes kasye in this area who I could speak to?

Proof for Review