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Decision making: Fishing production and fishers in the Black Sea

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1 **Decision making: fishing production and fishers in the Black Sea**

2

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20 **Abstract**

21 This paper explores empirical evidence as well as a theoretical model of fisheries in the
22 Black Sea which have become depleted as a result of both environmental degradation and
23 overexploitation. We examine overfishing and the optimal fish catch, and derive Evolutionary
24 Stable Strategies (ESS) from a game theory perspective by using agent risk profiles. We explain
25 how risk-averse fishers may choose to fish at unsustainable levels, even though it may reduce
26 their overall fish catch in the long run. Risk attitudes of artisanal fishers within the frameworks
27 of expected utility and prospect theories also have implications on risk aversion and non-
28 cooperation. We explore how social norms between fishers could encourage cooperation in
29 fishing at sustainable levels, but finds that these norms and information networks have not
30 developed enough in the Black Sea to be effective.

31

32 **Keywords**

33 Black Sea; Fisheries; Risk profiles; Game theory; Artisanal fishers and risk aversion

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39 **1.1. Introduction**

40

41 Tragedy of the commons as well as Elinor Ostrom's work on non-tragedy of the
42 commons have been applied to environmental issues extensively. Given the evidence for the
43 depletion of some natural resources, such as fish in the Black Sea, various riparian and non-
44 riparian governments and international organizations have acted to stop and reverse the depletion
45 trends by various meetings and agreements (Ostrom, 2000; Dietz et al., 2002; Schlager and
46 Ostrom, 1992; BSC, 2009; GFCM, 2012). As we study risk profiles and different fishing

47 strategies in this paper, we examine the situations under which individual fishers can be
48 persuaded to adopt evolutionary stable fishing strategies. The size of the fishing firm we
49 consider here is small and artisanal, which is representative of many fishing communities in the
50 Black Sea (Berkes, 1986). The first sections of the paper are a literature survey on Black Sea
51 fisheries, the time trends in landed fish, and game theoretic evolutionary stable fishing
52 strategies. Risk profiles of artisanal fishers, prospect theory and conclusions are presented in the
53 final sections.

54 **1.2 Literature Survey on Black Sea Fisheries**

55 The Black Sea is classified as an inland sea and has an area of 436,400 km² (168,500 sq
56 mi), excluding the Azov Sea (Bakan and Buyukgungor, 2000). It is surrounded by six riparian
57 countries and has a drainage basin over five times its own area, mainly from the deltas of the
58 Danube and Dnieper Rivers (Mee, 1992). (Figure 1).

59 **Insert Figure 1 here**

60 The industrial activities of the region had taken a severe toll on the ecosystem. One of the
61 most severe crises facing the Black Sea caused directly by human activity is the eutrophication
62 of the waters- that is, the reaction of an aquatic ecosystem to an unexpected influx of fertilizers
63 and/or sewage (Mee, 1992). Up to 95% of the shallow NW Black Sea and Azov Sea are prone
64 to hypoxia, which resulted in the elimination of entire species of deep-water fish, which can no
65 longer survive at low levels of oxygen. Mee (1992) used this ecological process to explain the
66 sudden collapse of the fishing industry since the 1960s and 1970s. Only six of the 26 species of
67 fish that were commercially caught and sold in the mid-20th century remain abundant enough to
68 be viable economically to harvest (Mee, 1992). Overexploitation has also depleted fish stocks

69 (Leppakoski and Mihnea, 1996; Turan et al., 2005). This is partly caused by variations in
70 regulations over the years. Policies to boost the fishing economy in the 1980s reduced size
71 restrictions on certain fish caught, allowing much more to be harvested, resulting in a rate of
72 fishing that could not be naturally sustained. The collapse of the landed catch in 1990 was also
73 due to the growth of jelly fish (comb jelly or *Mnemiopsis leidyi*), which scavenged the eggs, and
74 the larvae of the important fish in the Black Sea region (Turan et al, 2005). Leppakoski and
75 Mihnea (1996) report that the Romanian Coast fish harvests of sturgeon (*acipenser*), Black Sea
76 turbot (*psetta*), anchovy (*engraulis*), and gobies all were much lower level in 1990 than in
77 1971. Daskalov (2002) attributes the rise of total catch in the 1970s to a general shift away
78 exploitation of large predatory fish to smaller pelagic fish.

79 A plot of both total and anchovy fish catch for the Black Sea from 1970-2010 is
80 given in Figure 1. Total catch began to increase in the mid-1970s, with the average catch more
81 than doubling between 1975 and 1985. However, the biomass began to be depleted due to comb
82 jelly invasion and overexploitation, so that by 1990, the total catch had fallen to levels below
83 that of 1970. The maximum sustainable catch (MSY) threshold must have been crossed at
84 some point during the late 1970s and early 1980s because the yearly catches sharply dropped
85 soon afterⁱ. Due to these trends, it is more desirable to remain at sustainable fishing levels in
86 the short run even when more fishing is possible, to retain the biomass to sustain future fishing
87 (Die and Caddy, 1997; Garcia et al., 1989).

88 **Insert Figure 2 here**

89 This 1990 fisheries crisis prompted the 1992 Bucharest Convention by the Black Sea
90 Commission for protection against pollution with a permanent secretariat which is still in
91 existence today.ⁱⁱ Table 1 reports the relative percent of fishing stock composition for the six

92 major Black Sea riparian countries in 2008 based on the General Fisheries Commission for the
93 Mediterranean (GFCM) (2012) database.

94 **Insert Table 1 here**

95 Anchovy is the largest catch for all countries at over 70%, with sprat coming in second at almost
96 20%. Together, these two species account for over 91% of all landings in fisheries across the
97 Black Sea, providing indicators for analyzing economic impacts of the changing biodiversity of
98 the region. During the 1960s and 1970s anchovies only made up around 54% of the total catch,
99 and the rest were several other species such as the mackerel, whiting, and bonito. Overfishing
100 and the ecological crisis of the late 1980s caused a substantial shift in the species makeup of the
101 region, and many smaller species either died out or ceased to be included in the fishing stocks
102 (GFCM, 2012; Eremeev and Zuyev, 2007; Oguz, 2005). Commercial species soon collapsed
103 under the combination of overexploitation and new invasive predators, so that harvest yields
104 sharply dropped across the basin by 1990. By the late 1980s, the fishing industry in the region
105 directly supported almost two million inhabitants (Travis, 1993). Direct harvest losses incurred
106 from the crash of the early 1990s cost the basin \$240 million USD.

107 The reaction of local communities to these changes has been examined by analyzing the
108 small scale fishing industry of the Eastern Black Sea from a new institutional economics
109 perspective- that is, how small groups and communities both manage and govern their shared
110 resources (Knudsen, 2008). Knudsen studied the traditional ecological knowledge (TEK) and
111 the local customs of the community of Carsibasi on the Eastern coast of the Black Sea as a case
112 to determine how these small fishing towns conduct business in the absence of formal
113 regulations and in the face of the changing ecological makeup of the sea. Even though Turkey's

114 Ministry of Agriculture updates the national fishing regulations every two years, regulations on
115 small boats are virtually non-existent due to the near-impossible task of enforcement and the
116 implicit recognition that such regulations would cripple small subsistence fishers. Locals instead
117 rely on a network of informal regulations and unwritten rules to bring order to the short but
118 frantic fishing season in late spring/early summer. Knudsen (2008) found that it is the “ethical
119 know-how” of fishing based on mutual respect and unspoken rules of courtesy amongst the
120 fisherman of the community that allows the small-boat industry to thrive from generation to
121 generation while also adapting to the changing ecological landscape of the Black Sea coast.
122 Knudsen’s analysis shows how artisanal and local fishers have had to adapt to the changing
123 biological makeup of the Black Sea, and how their economic livelihood is directly related to the
124 amount of fish available to them.

125 **1.3 Maximum Sustainable Yield**

126 While individual agents act and adapt to the conditions, the means of fishing, such as
127 blast fishing, bottom trawling and bycatch, lead to overfishing that adversely affect the future
128 biomass (see Reeves Reeves and Notarbartolo di Sciara, 2006; Gerlak, 2004). The concept of
129 MSY is an estimate of an optimum fish catch each year that both maximizes current fish yield
130 but also leaves enough of the biomass still unexploited in the sea to continue the yield in future.
131 A function that can accurately model the maximum sustainable that yield obtainable by all
132 fishing parties is given by Knowler et al. (2001).

$$133 \quad Q_{t+1} = \sigma * S_t \quad [1]$$

134

135 Here, Q_{t+1} is the total exploitable fish population available in the next year, σ is the natural
136 survival rate of fish in the environment and S_t is the population that survives the year's harvest.
137 S_t can be expressed as

$$138 \quad S_t = Q_t - h(Q_t, E_t) \quad [2]$$

139 where Q_t is the total population of fish at time t and h is a function of fish catch, which is a
140 function of both Q_t and E_t , the fishing effort exerted over the year.

141 Various methods of estimating a value for the amount of fish which can be harvested
142 each year to maintain MSY have been proposed (Die and Caddy, 1997; Garcia et al., 1989).
143 This estimator is an important component of an effective fisheries management structure for
144 several reasons. First of all, many countries with fishing economies are considered “developing”
145 and may not be able to afford regular, formal assessments of fish stock that occur in more
146 developed countries (Die and Caddy, 1997). Most riparian countries around the Black Sea are in
147 this classification and an estimator equation provides them with a theoretical limit on fishing to
148 sustain the population without the costly physical assessment. Secondly, a theoretical estimate
149 enables comparisons with current fishing levels to be able to make accurate predictions and
150 policy recommendations for the ecological preservation of the species. Die and Caddy (1997)
151 and Garcia et al, (1989) underline the limits of applying MSY estimators. The MSY should
152 not be used as a benchmark or a goal for fish harvests both because of its unpredictability and the
153 dangers of overexploitation even by a very small amount. Food and Agricultural Organization
154 (FAO) of the UN and its Code of Conduct for Responsible Fisheries specifically differentiates
155 between reference points not to be approached, such as the MSY value, and “benchmarks for
156 safe exploitation” (FAO, 1995; Die and Caddy, 1997).

157 The MSY estimator is an important piece in a game theory model for maximum payoffs
158 which must be taken into account to study allocation between parties. Black Sea fishing is
159 plagued with many problems, yet cooperation will increase the total available fish population by
160 a series of mutual reductions in both pollution and overexploitation. The section below models
161 one of these problems, that of overfishing, where the behavior of fishing parties are examined to
162 see under which conditions cooperation will occur. The basic concepts of the model can then be
163 extended to multiparty cooperation on overexploitation.

164 **2.1 Evolutionarily Stable Strategies (ESS) in a Fishing Game**

165 A game theory perspective can help explain environmental issues by indicating what
166 actions people would choose to take regarding the harvesting of natural resources, and how these
167 actions would impact the environment. Here we model the behavior of two artisanal fishers, the
168 dominant firm size of the Black Sea region. This model can also be extended to the two-nation
169 bilateral game on cooperation, or in equation form, to multilateral co-operations.

170 In a model of a fishing game, one can determine how intensively fishers would choose
171 to harvest fish based on how many fish they expect to catch and how many fish they expect the
172 other fisher to catch. Based on this knowledge, one can find a best strategy, or Nash equilibrium
173 (NE), or in many of these instances, multiple best strategies for players to play. In the multiple
174 best-strategy situations, over multiple rounds, the game may eventually converge to each fisher
175 playing one particular strategy, called an evolutionarily stable strategy, or ESS. To determine
176 which NE are ESS, they must meet one of two conditions presented below. Let A be the payoff
177 of a strategy, let there be two strategies i and j , and let $*$ denote Nash strategy. Then

178

179 Condition 1: $A_{i^*i^*} > A_{ij^*} \quad \forall j \neq i$ [3]

180

181 Condition 1 indicates that the payoff of both players using the NE strategy is greater than the
182 payoff of one player using a NE strategy and the other player using any other strategy.

183

184 Condition 2: $A_{i^*j} > A_{jj} \quad \forall j \neq i$ [4]

185

186 Condition 2 indicates that the payoff of one player using the NE strategy and another player
187 using any other strategy is greater than the payoff of both players using strategies that are not the
188 NE strategy (Barron, 2008).

189 Once cooperation quotas are set for limiting fish catch, one can look at various scenarios
190 to see when fishers will cooperate with guidelines. Below is an example of a rather utopic
191 game in which two players can either cooperate (restrict) with quotas or not (Matrix A).
192 Suppose the total fish catch has a value of 4. Monitoring is costly and suppose, if incurred,
193 monitoring costs 6. The payoffs can be structured such that the fishers are promised a payoff of
194 5 each (2 as catch plus a one-timeⁱⁱⁱ subsidy of 3 each), the latter of which equal monitoring costs
195 (if incurred) if they choose to cooperate within the sustainability guidelines. The present day
196 payoff to the players in the game is now greater if they cooperate.

197

198

199 **Matrix A**

200

201

	Fisher 2	
	Cooperate	Don't Cooperate

202	Fisher 1	Cooperate	5,5	0,4
203				
204		Don't Cooperate	4,0	2,2

205

206 If both players choose to cooperate, then the fish population will remain at a sustainable level,
 207 allowing both fishers to gain a value of 5 from the sea, in catch and in subsidies. If one
 208 fisherman chooses to cooperate and the other does not, then the party that who does cooperate is
 209 able to take advantage of the game to gain a value of 4, while the other party loses out and gains
 210 nothing. While the fisher that chooses not to cooperate gains more than the other fisher, the
 211 fisher only gains 4, which is still less than he could have received had both of the fishermen
 212 cooperated. If neither player cooperates, then both of the fishermen only receive a catch value of
 213 2 from fishing.

214 Calculating the NE from the game will result in two pure strategies and one mixed
 215 strategy. The first pure strategy is for both players to cooperate, the second is for both players
 216 not to cooperate. The third is a mixed strategy where both players cooperate $2/3$ of the time and
 217 not cooperate $1/3$ of the time. Played among rational players, these strategies may occur in one
 218 round, but played in multiple rounds and with multiple players, the strategies may move toward a
 219 particular equilibrium, depending on the characteristics of the players. The equilibrium that the
 220 players will move toward can be determined by testing for the evolutionary stable strategy. This
 221 strategy would be adopted by the entire players of fishers, and would not be moved away from,
 222 even if occasionally fishers deviate from the strategy. We can show the three NE of this game:
 223 X_1, Y_1 is where the players both cooperate, X_2, Y_2 where they both do not cooperate and X_3, Y_3
 224 is the mixed strategy. The values in equations 5 to 7 are probabilities.

225

226 Nash Equilibria: $X_1 = (1, 0)$ $Y_1 = (1,0)$ [5]

227 $X_2 = (0, 1)$ $Y_2 = (0,1)$ [6]

228 $X_3 = (2/3, 1/3)$ $Y_3 = (2/3,1/3)$ [7]

229

230 Testing these three NE for ESS, we find that condition 1 is met for only the pure NE strategies
231 (of players both cooperating and both not cooperating)^{iv} but not for the mixed strategy. In other
232 words, in an environment with many fishers playing similar games, both fishers will tend to
233 follow the pure strategies of either cooperation or non-cooperation with guidelines. Which NE
234 they will move towards depends on the initial conditions with respect to the mixed NE. For this
235 example, if initially more than 2/3 of fishers choose to cooperate in fishing, then the population
236 will move away from the mixed NE towards the pure NE where all of them will cooperate. This
237 could also be called moral or societal pressure for the higher aim. If initially less than 2/3 of the
238 fishers choose not to cooperate in fishing, then the population will move in the opposite direction
239 towards the pure NE of all of them non-cooperating ((Figure 3).

240

241 **Insert Figure 3 here**

242

243 The analysis of the ESS indicates that it would take a significant portion of the fishers to
244 cooperate in fishing before permanent cooperation could be achieved. However, if enough
245 fishers cooperate, then the ESS indicates that a healthy level of fishing that protects the biomass
246 could be achieved by limiting total catch to the MSY estimate.

247

248 **2.2 An Alternative ESS Game: What if there are no incentives for cooperation?**

249 Suppose that there are no incentives for cooperation. Such a game is given in Matrix

250 B below:

251

252 **Matrix B**

253

Fisher 2

254

Cooperate

Don't Cooperate

255

Fisher 1

Cooperate

5,5

0,5

256

257

Don't Cooperate

5,0

2.5,2.5

258

259

260 In this situation, cooperation or non-cooperation by a single party have the same payoffs (5)

261 unless both parties do not cooperate. Then the payoff for each is 2.5. In this game, there are two

262 pure NE where the players will either both choose to cooperate or both choose to not cooperate.

263 However, only one ESS strategy may be eventually adopted by all fishers over multiple games

264 among multiple fishers.

265

266

267 Nash Equilibria: $X_1 = (1, 0)$ $Y_1 = (1,0)$

268 $X_2 = (0, 1)$ $Y_2 = (0,1)$

269

270 Testing for ESS, we find the payoff of the two strategies that are not the NE are higher than the
271 payoff of one player using the NE strategy and the other player using any other strategy. This
272 illustrates that both players playing cooperation is not an ESS but both players playing 'don't
273 cooperate' is an ESS strategy. The fishers over time will move toward this ESS strategy of non-
274 cooperation. Therefore, if the payoff to the party who does not cooperate is the same as the
275 payoff if they cooperate, non-cooperation by **all** parties is the ESS solution. This is not a
276 socially desirable outcome for the preservation of the environment and of the fish biomass.

277

278 **2.3 Overcoming the Problem of Non-Cooperation**

279 Finding that non-cooperation is the only ESS NE solution for the example in Matrix B
280 may help explain why we observe tragedy of the commons with respect to fisheries in most
281 emerging economies, as well as in the Black Sea. The results of the previous section, the ESS
282 and prisoner's dilemma models, may indicate that it is difficult or even impossible for players to
283 cooperate without any outside intervention, but other factors may exist that can support
284 cooperation.

285 Empirical tests of prisoner's dilemma games have often found that players take actions
286 that do not fit the standard expectations for the game. For example, in a public goods game in
287 which players are given an endowment and make the choice to contribute money for a collective
288 good, the standard game theory model indicates that no players will contribute to the collective
289 good, as there is no individual incentive for them to do so (Ostrom, 2000). This is similar to the
290 prisoner's dilemma and ESS models for fisheries where the best strategy for each player is to not
291 cooperate with one another to gain a higher payoff. When the game is tested among
292 participants, players tend to contribute between 40 to 70 percent of their endowments in the first

293 round, and while contributions fall in repeated rounds, they remain above zero. Finally, if
294 players are given the option to punish other players, some will punish players who do not
295 cooperate, even though they should have no incentive to do so. The results from these games
296 indicate that players tend to cooperate to a greater extent than standard models would predict
297 (Ostrom, 2000). If these experimental observations are extended to the case of fishers in the
298 Black Sea, then it is possible that individuals will be more likely to cooperate with one another
299 successfully, such as in the Carsibasi case in Turkey.

300 To determine whether players can cooperate, it is important to explain why they are not
301 following the NE strategy, even though it would appear to be in their self-interest to do so.
302 Ostrom (2000) explains these results by differentiating between three types of players. “Rational
303 egoists” fit the traditional economic model of players who rationally seek to maximize their own
304 gains. “Conditional cooperators” are players who are willing to cooperate to achieve higher
305 gains so long as they expect other players to cooperate as well. Estimates find these people make
306 up a significant proportion of the population, ranging from 40 to 60 percent of people. They
307 attach an extra value to trust and cooperation, which can make their internal payoffs different
308 than just the monetary values that are expressed in the game. “Willing punishers” are players
309 who choose to punish players who do not cooperate for the common good, even though it may be
310 costly to them. The presence of willing punishers and conditional cooperators who are more
311 willing to cooperate and enforce cooperation can prevent situations similar to the prisoners’
312 dilemma from occurring (Ostrom, 2000). The presence of these types of players in the
313 population of fishers would increase the potential for cooperation.

314 A variety of contextual factors are important to whether individuals will be able to form
315 social norms to cooperate and govern a common resource effectively. One important factor is

316 whether the use of the resource can be monitored (Dietz et al., 2002). While observing the total
317 amount of fish in the sea is not a feasible possibility, local fishermen may be able to monitor the
318 people who are fishing in the sea (Acheson, 1975). Another important factor is whether the
319 economic system is in a state of rapid transition, since a stable system of social norms may be
320 unable to develop (Dietz et al., 2002). Face-to-face communication is also an important
321 determinant of whether cooperation will occur. In experimental tests of the prisoner's dilemma,
322 face-to-face communication was a major determinant of the level of cooperation that occurred
323 (Ostrom, 2000). The Black Sea is a fairly large body of water with many different languages
324 spoken on its shores, so face-to-face communication between everyone would be impossible, but
325 smaller local groups of fishermen along a national shore would possibly be able to develop these
326 relationships.

327 For social norms to successfully develop, the group must be able to exclude outsiders to
328 control entry into the group to prevent a large influx which would potentially destabilize the
329 system. Once again, on the level of the entire sea this would be difficult, but in local groups of
330 fishers it would be possible. This type of cooperation and social norms are similar to the TEK
331 and social structure observed in the Carsibasi region.

332 Finally, fishers would have to take the responsibility to monitor and enforce the rules
333 governing fair usage of the waters (Dietz et al., 2002). At the local level this would be possible,
334 but not guaranteed. Overall, there are some conditions in the Black Sea that would encourage
335 workers to cooperate to take care of the fisheries, but other factors that may discourage
336 cooperation. Based on the empirical evidence showing that fish populations have decreased over
337 time, these social norms appear to not have developed enough to prevent overexploitation.

338 Government actions can be taken to encourage the responsible use of the sea, yet policies
339 that focus on rules and regulation tend to harm social norms that direct the use of the common
340 sea. Government regulations towards the commons tend to be ineffective because they are
341 slower to react to changes in the social, political, and economic setting in which they are
342 implemented, which often makes them ineffective. Policies towards the common resource of the
343 sea also tend to be difficult to enforce, so fishers can often circumvent restrictions (Dietz et al.,
344 2002). Experimental evidence also indicates that government programs and rules to encourage
345 responsible fishing could actually harm social norms that encourage farmers to cooperate. In
346 tests of prisoners' dilemma games, imposing external incentives to cooperate on players made
347 them much less likely to cooperate after these incentives were removed (Ostrom, 2000).
348 Evidence indicates that directly regulating fisheries would potentially crowd out social norms
349 and would not be an effective solution to overexploitation.

350 The better government policy would be to support social norms on a local level that
351 encourage fishers to cooperate and conserve resources. Governments can encourage these norms
352 by respecting the rights of groups of fishers to organize and by giving them a medium to settle
353 their disputes. This will legitimize and strengthen the system of norms without harming the
354 system (Ostrom, 2000). Governments in the Black Sea can use these strategies to support
355 cooperation among fishers in the Black Sea without relying on extensive rules and regulations.

356 The games discussed so far show the importance of payoffs and social norms to reach
357 desirable social outcomes for preserving MSY. Risk preferences of fishers also modify games
358 when a player's perception of risk often create results that do not match model predictions. In
359 the next section, we discuss risk preferences and how they may further affect artisanal fishing in
360 the Black Sea.

361

362 **3.1 The Influence of Risk Preference on the Fishing Game: Expected Utility Theory and**
363 **Prospect Theory**

364 Factors of risk and loss aversion of artisanal fishers will also play an important role in
365 determining which NE players will choose to play. In choosing a strategy, each player faces
366 uncertainty about the strategy the other player will select. When players take this risk into
367 consideration, they often face choices between a risky strategy (with both a higher potential
368 payoff- higher possibility of a loss), and a safe strategy (with a lower payoff-lower possibility of
369 a loss). For example, in the previous ESS game between two fishers (Matrix A), two pure NE
370 would be played which were ESS but between the two, cooperation would maximize the gains
371 for both players. That strategy for both is then *payoff dominant*, indicating that players should
372 play this strategy to receive the highest payoff of 5. Yet players who are *risk-averse* would
373 dislike the possibility that they could gain nothing, and could avoid the risk by choosing to not
374 cooperate, allowing them to get payoffs of either 4 or 2. In this case, risk-averse players with
375 a short time horizon and a large discount rate for the future will choose to not cooperate, which is
376 considered the *risk dominant* strategy. This is a further refinement of the findings of ESS
377 strategies and the outcome of non-cooperation is not socially desirable.

378 Some scholars have argued that rational players should always choose the payoff
379 dominant strategy because they expect to maximize their gains and they expect the other player
380 to do so as well. This argument relies on the idea that players will be able to make decisions
381 based on a “collective rationality” where “rational individuals will cooperate in pursuing their
382 common interests if the conditions permit them to do so” (Harsanyi and Selten, 1988, p. 359).
383 However, other scholars reject this viewpoint and argue that risk-averse players will choose to

384 play the risk dominant strategy to avoid the possibility of a loss. They argue that it is not
385 possible for players to form together as one group that makes collectively rational decisions.
386 Because players will not successfully cooperate and make decisions together, they make
387 individually rational decisions in which they do not cooperate with one another, and are likely to
388 choose the risk dominant equilibrium (Straub, 1996)^v.

389 Experimental evidence indicates that participants tend to choose the risk dominant
390 equilibrium in many games^{vi}. These studies emphasize the importance of the risk dominant
391 strategy and indicate that the more risk-averse fishers are, the less likely they will be to cooperate
392 in some situations. Observation of each individual fisherman's preferences is not a realistic
393 option, but because individuals' social and economic environments have been shown to affect
394 risk preferences, they can give some indication as to how risk-averse the players would be.

395 Past macroeconomic experiences, such as an economic recession, have been found to
396 increase risk aversion even after the event passes, although the effect eventually fades. For
397 younger individuals who have less lifetime experience, this effect is also greater (Malmendier
398 and Nagel, 2011). Many of the fishers in Black Sea have been exposed to negative economic
399 conditions in the Soviet Union following its dissolution in the 1990 s, when growth in the region
400 was highly unstable. Based on these economic experiences we can expect most of the fishermen
401 to be more risk-averse and less likely to cooperate with one another.

402 Differences in risk taking by gender may also play a role in how risk-averse
403 individuals may be. Many studies have found that women tend to be more risk-averse than men
404 regarding financial risk taking in the United States (Jianakoplos and Bernasek, 1998), and in
405 making consumer decisions and lifestyle choices (Hersch, 1996). While generalizing the data

406 to other situations and individuals outside the United States is very problematic, these studies
407 may indicate that the fishers in the Black Sea, who are generally men, would be more risk-
408 averse if their group included a larger proportion of females to males. We do note, though, that
409 gender differences in risk aversion for small agents in environmental studies need to be studied
410 further before any generalizations can be made at present.

411 These observations on how fishermen would view uncertainty generally rely on a
412 traditional economic view of risk known as Expected Utility Theory (EUT). EUT generally
413 adopts the view that players are endowed with a certain preferences towards risk that make them
414 either risk-seeking, risk-neutral, or risk-averse. The preferences of a player are based on the
415 utility, value or satisfaction he gains from different amounts of income which can be expressed
416 as:

$$417 \quad U(s,d) = (s+d)^r \quad [8]$$

418
419 where s represents the initial endowment of money held by the individual, d represents the
420 amount of income gained by the individual, and r is some parameter that represents the rate at
421 which an individual's utility increase, and U(s,d) indicates the level of utility the individual
422 receives from the endowment and gain in income. EUT also finds that individuals will measure
423 the expected value of uncertain outcomes by combining the probability of each outcome with the
424 utility they would receive from it. This can be modeled with the equation:

$$425 \quad EU = \sum_{k=0}^n p_k U_k \quad [9]$$

427

428 where n is the number of possible outcomes, p_k is the probability of outcome k , and U_k is the
429 utility of outcome k . This model assumes that people will be consistently either risk-seeking
430 ($r > 1$) or averse ($r < 1$) depending on the parameter r (Harrison and Rutström, 2008).

431 While EUT may make sense in many situations, evidence from psychology indicates
432 that people often act in ways that do not match the model. One major problem with the theory is
433 that people's risk preferences are not consistent, and can vary between being risk-averse and
434 risk-seeking depending on the situation (Rabin and Thaler, 2001). The failure of expected utility
435 to accurately model human behavior has led researchers to modify expected utility theory and
436 develop another model for describing human behavior under risk, known as Prospect Theory
437 (PT). Prospect Theory argues that when people are presented with a risky choice, they do not
438 take into account their initial endowment, but are mainly concerned with how they frame the
439 choice as a gain or a loss. PT also finds that individuals generally frame a loss as being more
440 painful than an equally sized gain, a condition known as *loss aversion*. The findings of this
441 theory lead to a different utility function defined separately under gains and losses as

442
$$U(d) = d^\alpha \quad \text{if } d \geq 0,$$

443 and

444
$$U(d) = -\lambda(-d)^\beta \quad \text{if } d < 0 \quad [10]$$

445 where α and β are parameters for the level of risk aversion and λ is the coefficient of loss
446 aversion. Prospect theory also states that individuals attach much greater weight to low

447 probabilities than the measures found in expected utility theory. This difference can be
448 accounted for by a weighing function of the probabilities, which can be modeled by

$$449 \quad W(p) = p^\gamma / [p^\gamma + (1-p)^\gamma]^{1/\gamma} \quad [11]$$

450 where $W(p)$ is the weight attached to the probabilities, p is the actual probability, and γ is a
451 parameter defining how the probabilities are weighed. After the weighted probabilities are
452 accounted for, the expected utility is found in a similar way to expected utility theory with the
453 summation

$$454 \quad EU = \sum_{k=0}^n W(p)_k U_k \quad [12]$$

455

456

457 where n is the number of possible outcomes, $w(p)_k$ is the weighted probability of outcome k , and
458 U_k is the utility of outcome k (Harrison and Rutström, 2008). This model indicates that when
459 people are making risky choices, they do not have a consistent preference for risk, but make
460 choices according to how they weigh probabilities and frame the decision as a potential loss or
461 gain.

462 The Black Sea area has been subject to political turmoil, invasions of hostile species
463 and long term trends of pollution and overexploitation. Given the many problems faced by
464 fishers with the dwindling catch and landed fish in the Black Sea, the differences between EUT
465 and PT have important implications on how fishers will react to risk. Studies find that
466 individuals will be either risk-seeking for losses of moderate or high probability, risk-averse for
467 losses of low probability, risk-seeking for gains of low probability, and risk-averse for gains of a

468 moderate to high probability (Tversky and Kahneman, 1992). This structure, known as the
469 *fourfold* pattern, indicates that the fishers will make decisions based on whether they anticipate a
470 low or high probability of the other fisher defecting, and whether they frame receiving the lower
471 value as a higher loss or a lower gain. Given that the fishers obtain some value out of the fish
472 that they catch, it is reasonable to expect that they will view each outcome as either a lower or
473 higher gain, and not as a loss. Considering the evidence that players eventually tend toward the
474 risk dominant strategy, and the appeal of the risk dominant strategy to the other player, it would
475 also be reasonable to assume that the fisher would expect the probability that the other fisher
476 would defect to be at least moderate or higher. This indicates that in this situation both players
477 frame their payoffs as gains and expect there to be a moderate chance that the other player will
478 defect and substantially lower their payoff. According to the fourfold pattern, in this situation
479 we would expect the fishers to be more risk-averse, and thus less likely to cooperate.

480 Another important factor affecting player cooperation is whether players can
481 communicate with one another during the game. In the study of games with both risk and payoff
482 equilibria by Clark et al., (2001), players who were not allowed to communicate did not tend to
483 move toward a payoff dominant equilibrium but did tend to do so when communication was
484 allowed. These findings are very similar to the arguments in the previous section, which found
485 that social norms and communication can support cooperation between players. This may
486 indicate that with communication, trust and collective rationality may be able to develop, so that
487 players can make decisions in the best interest of the group, and not just for themselves as
488 individuals. If social norms and communication between multi-national Black Sea fishermen
489 can develop, fishers may be more likely to cooperate to keep the harvesting of fish at a moderate
490 level. While the continuing fall in the fish population indicates that fishermen have not yet

491 developed these norms, supporting cooperation and communication among the fishermen can
492 encourage them to fish at a more sustainable level.

493 Overall, we generally find that fishers' risk aversion would negatively affect their
494 ability to cooperate with one another to harvest fish at a sustainable rate. This is based on
495 observation of their lifetime experiences with economic depression, and the short time horizon
496 and a large discount rate for the future in which they frame the gains or losses that they
497 experience while fishing. Lack of trust and lack of strong social norms regarding fishing also
498 seems to weaken their ability to choose the risky strategy, even though it may be better for the
499 environment overall.

500

501 **3.2 Conclusions**

502 Both the empirical evidence and our theoretical model indicate that fisheries in
503 the Black Sea are strongly at risk of facing further decline. Many fish species have disappeared
504 over the past few decades, as pollution, invasion of hostile species and overexploitation
505 contributed to sharply declining fish catch. This phenomenon has many implications for the
506 household income and protein intake of households around the Black Sea.

507 Our theoretical model indicates that, although there is some possibility of
508 cooperation, the common property of the sea will tend to encourage risk-averse fishers to
509 overfish at unsustainable levels. Social norms may be one way of encouraging cooperation and
510 trust among fishers, but they have only developed in a limited way. These findings indicate that
511 government policy should focus on encouraging fishers to have individual incentives to restrict
512 how much they fish. The most effective policy for this would be for governments surrounding

513 the Black Sea to provide a network of information for fishers that choose to restrict their fishing
514 to a more sustainable level. The riparian countries have already been cooperating on limiting
515 pollution since the Bucharest Convention of 1992. However, there is little cooperation on
516 sustainable levels needed for maintaining future harvests, except randomly enforced local limits
517 on the size and type of catch. An information and education network could alter the payoffs to
518 fishers and also change their risk attitudes so that it will be in each of their interests to fish at a
519 level that the environment can support.

520 An area of research that should be addressed in future is a more detailed multi-
521 national study of the social norms and attitudes of individual fishermen in the Black Sea. By
522 gaining further understanding of these informal rules, governments in the region will be able to
523 work with fishers more effectively and successfully encourage them to fish at a supportable
524 level. From an empirical standpoint, spreading knowledge and awareness about the MSY of total
525 fish catch as well as potential biomass loss from pollution and species invasion could lead to a
526 greater sense of collective rationality. In a large basin region such as the Black Sea's, local
527 communities practicing sustainable harvests are not able to see the larger picture of runoff
528 pollution, overexploitation by other country fishers, or changing biodiversity. Reducing
529 aggregate fish catch to a sustainable level in such a large body of water will require both
530 education and coordinated policy action by individual countries and regional economic
531 coalitions.

532

533

534

ⁱ Note that all riparian countries except Turkey had political regime changes in 1990s which may have affected the catch but we do not have any studies on the impact of political changes in the fisheries sector.

ⁱⁱ For more information on the pollution control aspects and three protocols, see <http://www.blacksea-commission.org/>.

ⁱⁱⁱ We are not suggesting perpetual subsidies on fishing which are subject to potential abuse and asymmetric corruption. This is a one-time subsidy for this particular example. Past observations show that successful subsidies which achieve real outcomes are set for a short and limited time period and are not extended regardless of pressure and of bargaining.

^{iv} Calculations are not reported here for parsimony and are available on request.

^v The players' choice between choosing either a payoff or risk dominant strategy reflects a choice between two different methods with which each player can maximize their payoffs. By choosing a payoff dominant strategy, the player chooses a *maximax* strategy, in which he seeks to gain the maximum possible outcome. By choosing a risk dominant strategy, the player chooses a *maximin* strategy, in which he seeks to maximize the smallest possible gain he can receive with certainty (Pearman, 1977). The choice between either a maximin or a maximax strategy indicates two different ways players may choose to make decisions, depending on how much they prefer certainty over risk.

^{vi} An experimental study conducted by Schmidt, et al. (2003) tested players to find that players generally responded to changes in the risk dominant strategy, and did not respond to changes in the payoff dominant strategy. The authors argue that this study indicates that risk dominant strategies are important in determining whether players will be able to cooperate, and, while payoff dominant strategies are also important, they seem to have less of an effect (Schmidt et al., 2003). A study by Straub found that when players play repeated games, they tended to converge away from the payoff dominant strategy and toward the risk dominant strategy (Straub, 1996). Together, these studies indicate that players tend to be risk-averse and thus are less likely to cooperate to gain a higher payoff.

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Table 1. Black Sea Landing Composition by Country and Species in 2008 (in tons)

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Species	Bulgaria	Georgia	Romania	Russian Fed.	Turkey	Ukraine	Total	%
Anchovy	28.0	25938.0	15.0	9070.0	225344.0	4298.2	264693.2	71.74
Sprat	4310.0	0.3	234.0	7814.0	38999.0	21110.8	72468.1	19.64
Horse mackerel	180.0	8.0	11.0		14741.0	365.6	15305.6	4.15
Whiting		15.0	55.0	96.0	10986.0	8.6	11160.6	3.02
Bluefish	25.0				1787.0		1812.0	0.49
Mullet	0.0	1.0	8.0	81.0	1518.0	91.5	1699.5	0.46
Turbot	55.0		47.0		458.0	251.4	811.4	0.22
Red mullet	17.0				706.0	45.2	768.2	0.21
Picked dogfish	23.0		10.0			79.2	112.2	0.03
Pontic shad	29.0		47.0	2.0		16.6	94.6	0.03
Raja nei						54.2	54.2	0.01

Source: Background Documents on the Black Sea Fisheries, GFCM, Jan 2012, p. 14,
<http://151.1.154.86/GfcmWebSite/SAC/WGBS/2012/GFCM-Background-Doc-BlackSea-Fisheries.pdf>

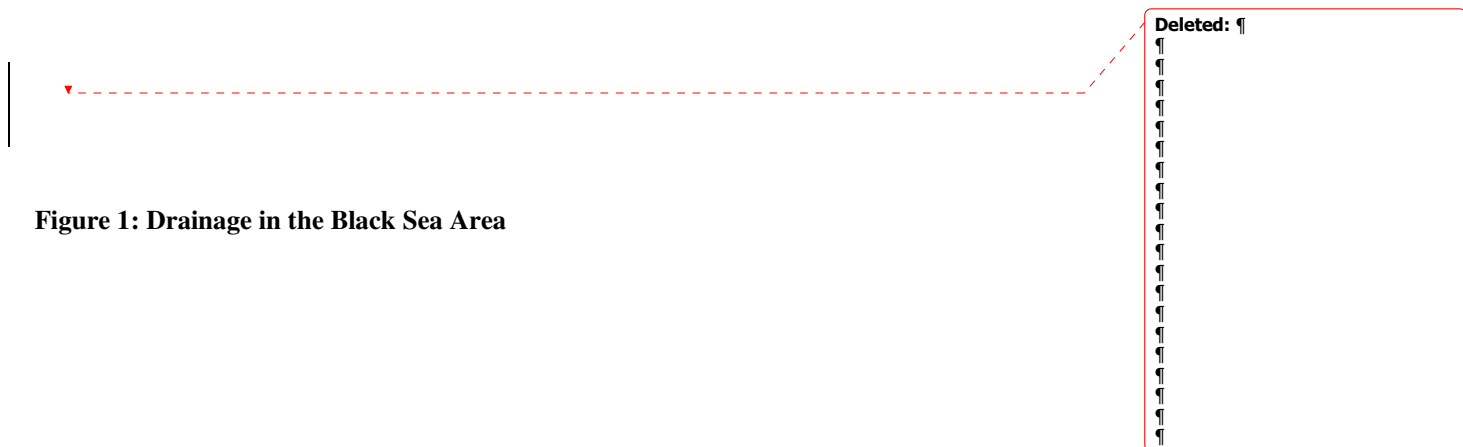
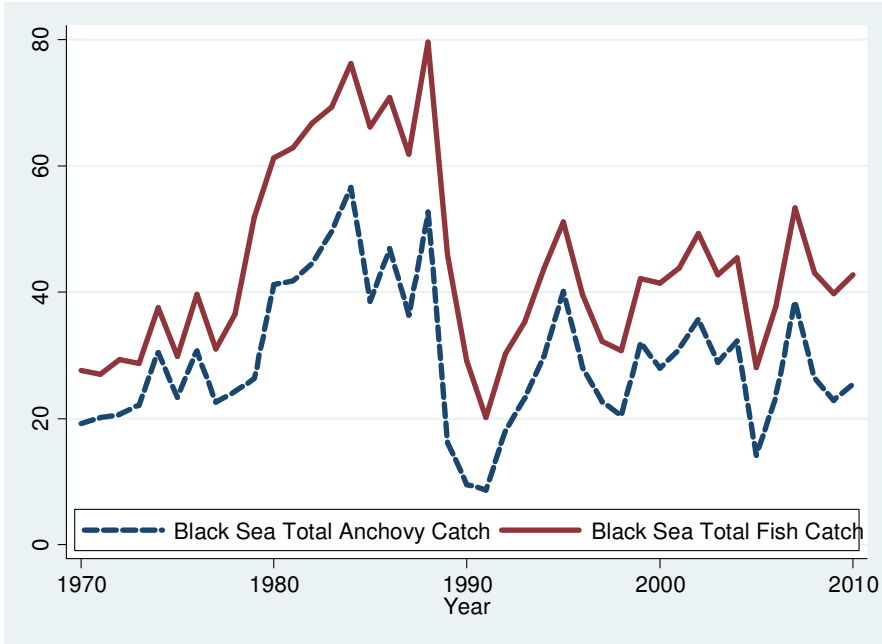


Figure 1: Drainage in the Black Sea Area



Source: With permission from *UNEP/GRID-Arendal, 2006*,
http://www.grida.no/graphicslib/detail/drainage-in-the-black-sea-area_f058

Figure 2: Plot of Total and Anchovy Fish Catch in the Black Sea, 1970-2010 (thousands of tons)



Source: Data plotted from http://www.fao.org/figis/servlet/SQServlet?file=/work/FIGIS/prod/webapps/figis/temp/hqp_9088285911198033225.xml&outtype=html

Figure 3: Movement Toward Pure Nash ESS and Proportion of Cooperating/Non-cooperating Fishermen

