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How did Fisheries Resource *Balistes capriscus* (Teleostei: Balistidae) Disappear in Coastal Waters of Ghana?

J. Aggrey-Fynn
Department of Fisheries & Aquatic Sciences,
University of Cape Coast, Cape Coast, Ghana

Abstract

The paper assessed the possible reasons for which *Balistes capriscus* (grey triggerfish) resource disappeared in coastal waters of Ghana. The study analysed relationships between seasonal maxima, minima and difference between maximum and minimum sea surface temperatures and grey triggerfish landings in coastal waters of Ghana. The study assessed a possible relationship between *Balistes* catch and fishing effort employed in the exploitation of the resource and possible scenarios that might have caused the collapse of the fishery. Catch-effort data of inshore *Balistes* (fish caught by inshore fishery) in Ghanaian waters from 1972 to 1991 were analysed. Temperature partitioning (Tp) was identified in between the period *Balistes* biomass increased with maximum temperature recorded from 1972 to 1976 and period *Balistes* biomass decreased with rising maximum temperature recorded from 1985 to 1989 in coastal waters of Ghana. A critical mean maximum temperature (Tc) was recorded in 1987 (Tc = 28.72 °C) in Ghanaian waters and thereafter the *Balistes* fishery resource declined to virtually zero biomass in 1989. Three probable scenarios which consider possible migration of triggerfish species, the increased death toll on the larvae and high energy cost of triggerfish parental-care in recent cooling conditions (T~22.0 °C) in Ghanaian waters were the discussed causes of the disappearance of the fish species. Therefore, the apparent disappearance of grey triggerfish in Ghanaian waters might have been caused by the extreme temperatures experienced from 1987 to date.

Keywords: Grey triggerfish, Gulf of Guinea, Sea surface temperature, Fisheries collapse

1.0 Introduction

The grey triggerfish species, *Balistes capriscus*, has a very wide bathymetric distribution in coastal waters of Ghana (MFRD, 1993) which occurs at near the bottom as well as near the surface of the sea (Aggrey-Fynn, 2009; Aggrey-Fynn and Obodai, 2009). The fish species was rated as one of the commercially valuable demersal fish in coastal waters of Ghana (FRU, 1981; Essuman and Diakité, 1990). Grey triggerfish off Ghana form part of the eastern stock of the triggerfish resource in the Gulf of Guinea (Stromme *et al.*, 1982; Stromme, 1983). The triggerfish species was at maximum abundance at the end of the 1970s in the Gulf of Guinea and at the beginning of the 1980s in the Canary current (Caverivière, 1982; Stromme *et al.*, 1982). The biomass of the eastern stock of grey triggerfish was estimated to be 500 000 and 140 000 tonnes in 1981 and 1986 respectively (Stromme *et al.*, 1982). The estimated biomass of triggerfish in May, 1981-March, 1982 in Ghanaian coastal waters was between 314 000 and 500 000 tonnes (Stromme *et al.*, 1982; Ofori-Adu, 1987; 1994), but there was management problem of triggerfish which was considered in 1987 as being under-exploited in Ghana (Ofori-Adu, 1987). Therefore, the present study is to assess the possible reasons for which grey triggerfish disappeared in coastal waters of Ghana.

2.0 Materials and Methods

Sea surface temperature (SST) data from 1974 to 2004 used were from the Marine Fisheries Research Division (MFRD), Tema of the Fisheries Commission, Ghana. The SST data were recorded from eight coastal stations spread along the Ghanaian coast. Daily SST were recorded directly from the sea by the MFRD field staffs at recording stations from west to east end of Ghana included: Half Assini (30 km), Axim (105 km), Cape Three Points (135 km), Takoradi (185 km), Elmina (230 km), Winneba (330 km), Tema (415 km) and Keta (545 km) (Fig. 1).

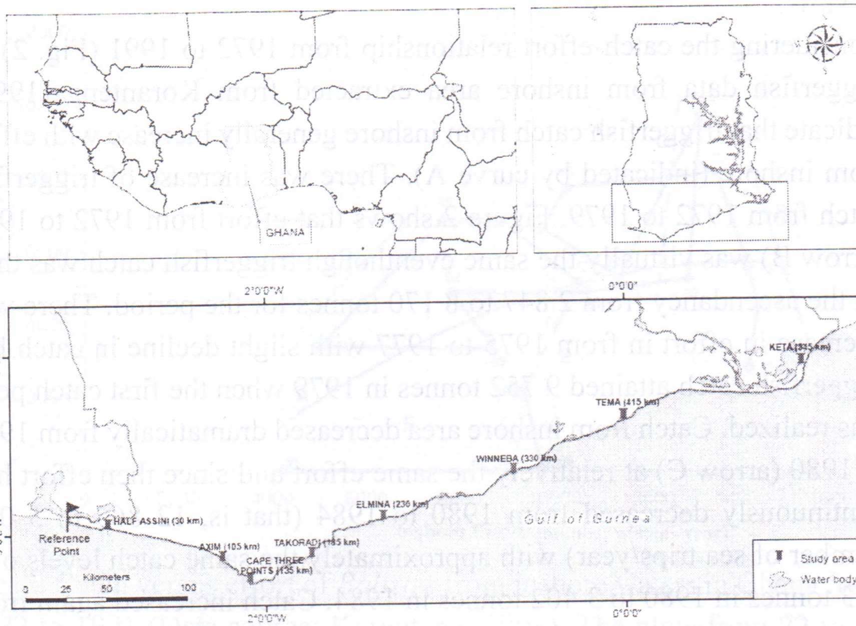


Fig. 1: Map of Ghana coast showing the SST data collection stations. Distances from reference point to Marine Fisheries Research Division recording stations (⛉) are shown along the coast of Ghana

Catch-effort data of *Balistes* occurring in inshore waters of Ghana from 1972 to 1991 were obtained from Koranteng (1998). *Balistes* catch data from inshore area were plotted against effort from inshore fisheries of Ghana over the period from 1972 to 1991 to ascertain periods *Balistes* biomass increased or decreased in coastal waters of Ghana. Catch-per-effort was also plotted against effort from inshore fisheries from 1972 to 1991.

Maxima mean daily temperature, minima mean daily temperature and difference between maximum and minimum mean daily temperature were related to the *Balistes* catch from inshore fisheries from 1972 to 1991.

Results

Considering the catch-effort relationship from 1972 to 1991 (Fig. 2) of triggerfish data from inshore area extracted from Koranteng (1998) indicate that triggerfish catch from inshore generally increase with effort from inshore (indicated by curve A). There was increase of triggerfish catch from 1972 to 1979. Figure 2 shows that effort from 1972 to 1975 (arrow B) was virtually the same eventhough triggerfish catch was then on the ascendancy from 2 847 to 8 170 tonnes for the period. There was decrease in effort in from 1975 to 1977 with slight decline in catch but triggerfish catch attained 9 752 tonnes in 1979 when the first catch peak was realized. Catch from inshore area decreased dramatically from 1979 to 1980 (arrow C) at relatively the same effort and since then effort had continuously decreased from 1980 to 1984 (that is, 12 865 to 5 002 number of sea trips/year) with approximately the same catch levels of 5 273 tonnes in 1980 to 3 402 tonnes in 1984. Catch increased again from 1984 to 1986 (arrow D) at increased effort. Catch from inshore area decreased progressively with effort from 1987 to 1991 indicated by arrows E and F (Fig. 2).

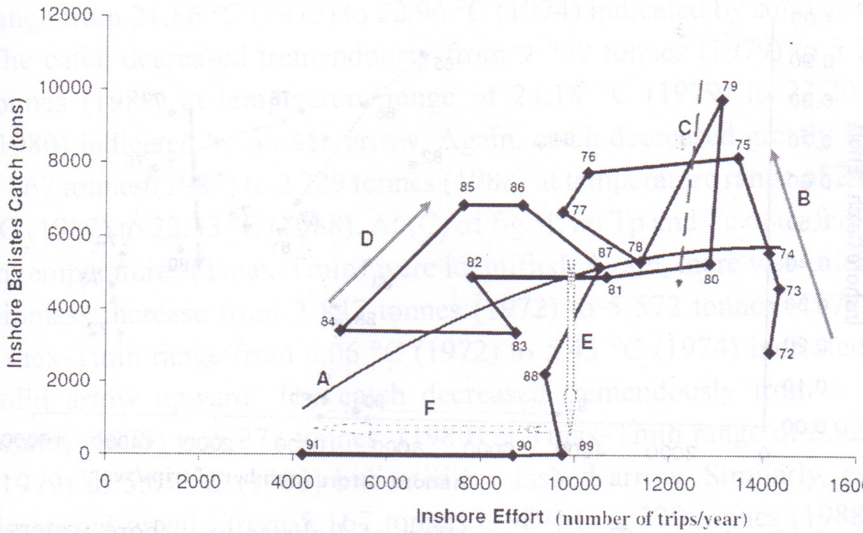


Fig. 2: Catch versus effort of *Balistes* from inshore waters in Ghana from 1972 to 1991 (Data source: Koranteng, 1998). The plots from 72 to 91 represent the period (year) from 1972 to 1991. Solid arrows (B and D) pointing upwards indicate scenarios where catch increased; broken arrows (C and E) pointing downwards indicate scenarios where catch decreased at virtually the same effort (number of sea trips/year)

The inshore catch-per-effort and effort relationship is shown in Fig. 3. The relationship shows that there was increased biomass at almost the same effort from 1972 to 1976 indicated by solid arrows pointing upwards. The triggerfish biomass decreased drastically from 1979 to 1980 at virtually the same effort indicated by dashed arrow downwards. From 1981 to 1984 effort from inshore area decreased with slight change in catch-per-effort. The triggerfish biomass was highest in 1985 and decreased afterwards up to 1991 indicated by dotted arrows downwards. The biomass decrease was quite significant from 1987 to 1989 at virtually the same effort; and from 1989 to 1991 there was virtually no biomass of the triggerfish resource in inshore waters of Ghana (Fig. 3).

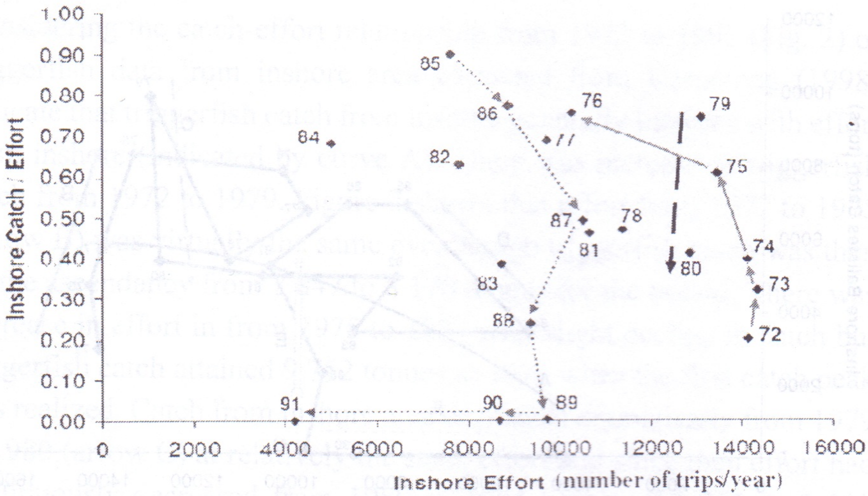
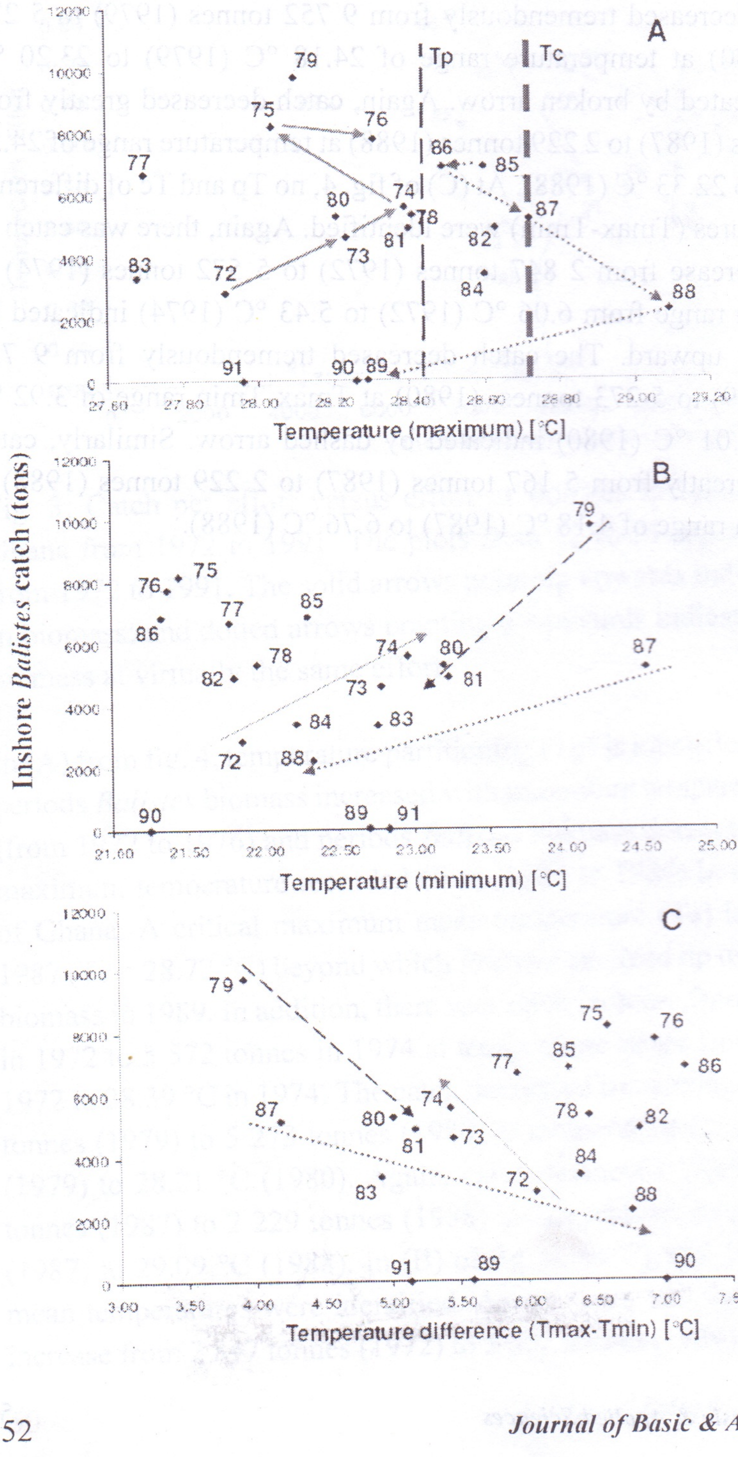


Fig. 3: Catch per effort versus effort of *Balistes* in inshore waters of Ghana from 1972 to 1991. The plots from 72 to 91 represent the year from 1972 to 1991. The solid arrows pointing upwards indicate increase in biomass; and dotted arrows pointing downwards indicate decrease in biomass at virtually the same effort

In (A) from fig. 4, temperature partitioning (Tp) is identified between the periods *Balistes* biomass increased with maximum temperature recorded (from 1972 to 1976) and periods *Balistes* biomass decreased with rising maximum temperature recorded (from 1985 to 1989) in coastal waters of Ghana. A critical maximum mean temperature (Tc) is identified in 1987 (Tc = 28.72 °C) beyond which *Balistes* declined up to virtually zero biomass in 1989. In addition, there was catch increase from 2 847 tonnes in 1972 to 5 572 tonnes in 1974 at temperature range from 27.91 °C in 1972 to 28.39 °C in 1974. The catch decreased tremendously from 9 752 tonnes (1979) to 5 273 tonnes (1980) at temperature range of 28.10 °C (1979) to 28.21 °C (1980). Again, catch decreased greatly from 5 167 tonnes (1987) to 2 229 tonnes (1988) at temperature range of 28.72 °C (1987) to 29.09 °C (1988). In (B) of fig. 4, no Tp and Tc of minimum mean temperatures were identified. Again, there was catch or biomass increase from 2 847 tonnes (1972) to 5 572 tonnes (1974) at temperature range from 21.86 °C (1972) to 22.96 °C (1974) indicated by solid arrow. The catch decreased tremendously from 9 752 tonnes (1979) to 5 273 tonnes (1980) at temperature range of 24.18 °C (1979) to 23.20 °C (1980) indicated by broken arrow. Again, catch decreased greatly from 5 167 tonnes (1987) to 2 229 tonnes (1988) at temperature range of 24.54 °C (1987) to 22.33 °C (1988). At (C) of fig. 4, no Tp and Tc of difference in temperatures (Tmax-Tmin) were identified. Again, there was catch or biomass increase from 2 847 tonnes (1972) to 5 572 tonnes (1974) at Tmax-Tmin range from 6.06 °C (1972) to 5.43 °C (1974) indicated by solid arrow upward. The catch decreased tremendously from 9 752 tonnes (1979) to 5 273 tonnes (1980) at Tmax-Tmin range of 3.92 °C (1979) to 5.01 °C (1980) indicated by dashed arrow. Similarly, catch decreased greatly from 5 167 tonnes (1987) to 2 229 tonnes (1988) at Tmax-Tmin range of 4.18 °C (1987) to 6.76 °C (1988).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Temperature (maximum) [°C]
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Temperature (minimum) [°C]
Inshore *Balistes* catch (tons)
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Temperature difference (Tmax-Tmin) [°C]

Fig. 4: Inshore *Balistes* catch versus temperature in coastal waters of Ghana. Plots indicate years from 1972 to 1991. (A) Solid arrows pointing upwards indicate increase in catch at temperature (maximum) range; Tp: temperature partitioning; Tc: critical temperature. (B) Dashed and dotted arrows pointing downwards indicate catch decrease, solid arrow pointing upwards indicates catch increase at temperature (minimum) range. (C) Dashed and dotted arrows pointing downwards indicate catch decrease, solid arrow pointing upwards indicates catch increase at temperature difference (Tmax-Tmin) range

Temperature difference at which *Balistes* biomass from inshore waters increased (from 1972 to 1974) and decreased (from 1979 to 1980, and from 1987 to 1988) in Ghana are shown in Table 1. From 1972 to 1974, there was increased maximum temperature (A) but the difference (0.48 °C) was narrow. There was moderately increased minimum temperature difference of 1.10 °C (B), and narrowly decreased Tmax-Tmin difference of 0.63 °C (C). From 1979 to 1980, there was narrowly decreased maximum temperature difference of 0.11 °C (A); moderately decreased minimum temperature difference of 0.98 °C (B); and moderately decreased Tmax-Tmin difference of 1.09 °C (C). From 1987 to 1988, there was narrowly decreased maximum temperature difference of 0.37 °C (A); widely decreased minimum temperature difference of 2.21 °C (B); and widely increased Tmax-Tmin difference of 2.58 °C (C) in Ghanaian coastal waters.

Table 1: Temperature difference at which *Balistes* biomass increase (from 1972 to 1974), and biomass decrease (from 1979 to 1980 and from 1987 to 1988) in coastal waters of Ghana (Fig. 4). Temperature difference in bracket, increase or decrease indicated

	Temperature difference (°C)		
	1972-74	**1979-80**	**1987-88**
(A)Temperature (maximum)	narrow, increase (0.48)	narrow, decrease (0.11)	narrow, decrease (0.37)
(B)Temperature (minimum)	moderate, increase (1.10)	moderate, decrease (0.98)	wide decrease (2.21)
(C)Tmax-Tmin	narrow, decrease (0.63)	moderate, increase (1.09)	wide increase (2.58)

4.0 Discussion

There has been a general believe among the fisherfolks in Ghana that the triggerfish has been overexploited. One of the questions followed in this study was whether the extreme local sea temperature conditions were primarily responsible for the collapse of triggerfish in coastal waters of Ghana. The relationship between maximum mean temperature and *Balistes* catch (Fig. 4) indicated a possible temperature partitioning (Tp) between *Balistes* catch or biomass increase from 1972 to 1976 and catch decline period from 1985 to 1989 in coastal waters of Ghana. Again, it was observed in Fig. 4 that beyond maximum mean critical temperature (Tc = 28.72 °C in 1987) *Balistes* species disappeared from 1988 onwards in Ghanaian waters. There is the likelihood that Tc is the "point-of-no-return" for triggerfish in Ghanaian coastal waters. The point-of-no-return is defined in this study as the maximum mean temperature of the sea beyond which the *Balistes capriscus* fish stocks might have disappeared or re-located as a result of warming sea conditions. It is known that warming in the sea results in rise in oxygen demand for marine organisms and also reduction in oxygen solubility (Pörtner and Knust, 2007) in the sea. High oxygen demand of fish species in the warming seas will affect aerobic respiration, and the results might be negative effect on growth performance of the triggerfish (Aggrey-Fynn, 2009), fish development, fecundity and recruitment (modified from Pörtner and

Knust, 2007). In this sense, it could be argued that *B. capriscus* fish stocks might have disappeared after the 1987 warming sea conditions and the fisheries resource could not recover afterwards and hence the collapse of triggerfish fisheries in Ghana.

Only catch-effort data from inshore area from 1972 to 1991 (Fig. 2) was reliable enough to be used to assess the fishing pressure on the *Balistes* fishery resource in Ghanaian waters. This was done to further ascertain the changes in the biomass of triggerfish during the period. These exercises were done to find a possible relationship between *Balistes* catch regime and sea surface temperature in coastal waters of Ghana. The catch-per-effort and effort relationship (Fig. 3) indicates scenarios where *Balistes* biomass increased from 1972 to 1976 at virtually the same effort; and *Balistes* biomass decreased considerably from 1979 to 1980 with the same effort and again, biomass declined from 1987 to 1988 with slight change in effort. The influence of minimum mean daily temperature and difference between maximum and minimum mean daily temperatures (Tmax-Tmin) on *Balistes* catch cannot be underscored (Fig. 4 and Table 1). This is because at virtually the same effort employed *Balistes* biomass from inshore area had increased (from 1972 to 1974) or decreased (from 1979 to 1980 and from 1987 to 1988) with varying temperature differences of minimum mean daily temperatures and Tmax-Tmin temperatures. The range of minimum mean temperature changes was moderate to wide in the periods of increased and decreased *Balistes* catch. From 1987 to 1988, the wide decrease in minimum mean temperature difference might have affected triggerfish spawning and/or migration pattern and hence the collapse of the resource. Similarly, the Tmax-Tmin temperature changes were moderate to wide temperature difference in the periods triggerfish biomass increased and decreased. Base on the knowledge of the biology of *Balistes capriscus* in coastal waters of Ghana (Ofori-Danson, 1981; 1990) and other species of triggerfish eg. *Xanthichthys mento* (Kawase, 2003), triggerfish spawning is successful in warm sea conditions. Also, *B. capriscus* larvae and juveniles had been recorded in seven cruises only during summer season in southern Brazilian waters (Matsuura and Katsuragawa, 1981).

The scenario that grey triggerfish migrated offshore could be a possible explanation to the recent apparent disappearance of the fish species in coastal waters of Ghana. It can be suggested that there was much more stable thermal conditions of the sea during major upwelling periods (Longhurst, 1962; cited by Ofori-Danson, 1990) in 1979 and 1987. However, there is evidence that intense cooling had persisted since 1988 to date during major upwelling seasons along the coast of Ghana with no indication of stable conditions (as experienced during 1979 and 1987) (Aggrey-Fynn, 2011). This is in agreement with observations of Bakun (1993) that there has been a long-term intensification of coastal upwelling in the Gulf of Guinea that may be related to global climate change. Eventhough Essuman and Diakitě (1990) acknowledged that the occurrence and concentration of triggerfish (like many schooling fish species) are influenced by upwelling and seasonal variations in temperatures of the sea at various depths the report does not elaborate on how this actually can occur. Nonetheless, the reports on migration of triggerfish from cold coastal waters as a result of cooling to join offshore pelagic stock throughout the year might give an insight to the role of intense cooling or intensification of minor upwelling in coastal waters of Ghana (Aggrey-Fynn, 2011) in the collapse of triggerfish fishery from 1988 to date. There are reports that average sea surface temperature during major upwelling season 100 km (further offshore) is constantly between 25 °C and 26 °C irrespective of the large annual variation in temperature over the continental shelf of Ghanaian waters (Houghton, 1976). This suggests there is a possibility that triggerfish which is sensitive to cold might migrate to warmer conditions further offshore during intense coastal cooling. It is therefore perceived that triggerfish might have migrated further offshore (which are not trawlable by inshore vessels due to uneven and rocky continental margins). Again, the minimum mean temperature recorded in Ghanaian waters has been low

(T~ 22.0 °C) after 1987 to date which is very much similar to the minimum mean temperatures prior to 1979. Such cooling condition of sea occurred prior to 1979 invasion of triggerfish and the same is being experienced after 1987 collapse of the species in coastal waters of Ghana. Koranteng (1984) attributed the sharp decline of *Balistes capriscus* landings of inshore trawlers during the cool season in Ghanaian waters due to gear switch of the inshore operators to purse seining for *Sardinella*. However, this study suggests that the decline in landings might have occurred due to migration of the triggerfish species to further offshore to spawn during this cooling period in Ghana. The recent cooling (after 1987 to date) during major upwelling period (Aggrey-Fynn, 2011) is likely to prevent the fish to return to Ghanaian coastal waters for breeding.

A second possible scenario is that, the cooling that occurred in recent times is likely to have had a major negative toll on egg development, as Cury and Roy (2002) states that minor changes in the timing or the intensity of a seasonal cycle of an environmental variable can have an important ecological impact. The breeding season of triggerfish which occur in October-December (Ofori-Danson, 1990) is a warm period in Ghana and therefore the breeding of the fish species might have been successful during the warm sea conditions (Aggrey-Fynn, 2011). There are other reports that larvae and juveniles of grey triggerfish in Southern Brazilian waters only occurred during summer season, a result obtained from seven cruises (Matsuura and Katsuragawa, 1981). Eventhough, some demersal spawners like *Oxymonacanthus longirostris* (monacantidae) are able to shift spawning seasons to suit water temperature conditions in order to produce well developed larvae (Kokita and Nakazono, 2000) there are no such reports on triggerfishes. Experiments conducted by Kokita and Nakazono on larvae of *O. longirostris* show that larvae which hatched at lower than natural optimal temperature were extremely under developed compared to larvae which hatched in natural optimal temperature conditions (Kokita and

Nakazono, 2000). Another report shows that larvae that are small and weak are highly susceptible to predation at the onset of exogenous feeding (Blaxter and Hempel, 1963). Possible predation on under-developed larvae coupled with low food concentrations (characteristic of tropical waters) and starvation (Kerrigan, 1997) might be a contributing factor in the survival of triggerfish larvae in Ghanaian coastal waters in recent times.

High energy cost of triggerfish parental-care in recent cooling conditions might be the third possible scenario of the disappearance of the species. It has been indicated that the species of *Balistes* and other triggerfish such as *Pseudobalistes flavimarginatus, Melichthys niger, Xanthichthys mento* and *Canthidermis sufflamen* show parental egg care by tending and guarding of eggs which includes fanning and blowing of eggs, and exclusion of intruders (Lobel and Johannes, 1980; Ishihara and Kuwamura, 1996; Kawase 2003).The energy used by the spawning adult to undertake such activities is likely to be high in the recent cooling periods identified in Ghanaian waters during spawning period of triggerfish. It is also known that breeding in cold temperatures increase the incubation time of embryos, parental care of a single clutch, and the associated metabolic costs to adults may be increased substantially by spawning at cooler sea temperatures (Richardson *et al.*, 1997). This implies the time and energy expend in parental egg care would be high in the phase of recent cooling conditions characterising the spawning period if the species should breed in coastal waters of Ghana. This high energy cost in breeding at low temperature conditions might have caused *Balistes capriscus* off Ghana to migrate to more suitable and energy-efficient breeding site.

Hence, the apparent disappearance of grey triggerfish since 1987 in Ghanaian waters might have been caused by the extreme temperatures that had prevailed during that period till today.

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