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RESEARCH ARTICLE

FEEDING HABITS OF TWO ESTUARINE FISHES FROM MANGROVE FORESTS AROUND AZAGNY NATIONAL PARK (CÔTE D'IVOIRE)

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Abstract

Mangroves wetlands provide many ecosystem services and are considered to be highly productive tropical ecosystems. This work aims to describe dietary composition of two estuarine fish inhabiting in mangrove forests of Azagny National Park. A total of 80 and 117 specimens of *Chrysichthys nigrodigitatus* and *Coptodon zilii* were respectively collected between March 2019 and February 2020 using gillnets and traps. The Relative Importance index (RI) was used to analyze the importance of prey items in stomach contents. The results indicated 10 prey categories such as insects, fish, molluscs, macrophytes, detritus, annelids, crustaceans, phytoplankton, zooplankton and eggs. Seven and eight prey items dominated by macrophytes were observed in *C. nigrodigitatus* and *C. zillii*, respectively, which gives them an omnivorous diet with preferences of macrophytes. Fish diets of both species overlapped moderately and showed significant differences (Chi-square, p<0.05). The large number of preys obtained tends to indicate a high availability of food resources in mangroves forests and the opportunistic diet of both species. Spatial variations in diet in three stations were not significant (Anova, p>0.05). This study provides further support on practices of aquatic management, especially agriculture, aquaculture and conservation.

Introduction:-

Mangrove wetlands are considered to be highly productive tropical ecosystems and occur on tropical and sub-tropical coastlines (Mumby et al., 2004; Paillon et al., 2014). These ecosystems provide many environmental benefits such as protect shorelines from erosion, maintain biodiversity and genetic resources, provide feeding, reproductive, shelter and nursery sites to several terrestrial and aquatic species, and others (Abuodha and Kairo, 2001; Mazda et al., 2002). In Côte d'Ivoire, mangrove forests stretch along Ivorian coast, from east to west, from Assinie-Mafia to Bliéron. Several works have shown that mangrove forests of Azagny National Park (ANP) provide a significant amount of fishery resources to supply the local market because there exist strong linkages between fisheries productivity and these wetlands (Primavera, 2005).

Among the species landed, *Coptodon zilii* (Gervais, 1848) and *Chrysichthys nigrodigitatus* (Lacepède, 1803) are dominant fishes of commercial catches and are highly valued fish for local populations (Nwachi, 2016). They are

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economically and ecologically important as food fish, for aquaculture, commercial aquarium trade, weed control and recreational fishery (Mehanna, 2004). Both species are known from most basins of West Africa, such as the Niger, Volta, Bia, Bandama, extending from Senegal to Angola (Risch, 2003; Teugels and Thys Van Den Audenaerde, 2003). Given the importance of both species, the knowledge of feeding behavior is necessary for conservation. To conserve fishes, data of food items and feeding habits for each fish species are very important to know the relation between all species live in the same ecosystem (Kouamélan et al., 2000; Saikia, 2015). Also, this information can be useful in finding out the distribution of a fish population for successful management of fishery (Paugy and Lévêque, 2006; Allan and Castillo, 2007).

Several studies have examined the diet of both species in various aquatic environments. Some preys such as insects, macrophytes, detritus, molluscs have been reported in diet of both species (Dadebo et al., 2014; Okyere and Boahemaa- Kobil, 2020), which can cause dietary overlap and competition for food search (Scharf et al., 2000). Although the diet has been studied by many authors, both species are able to feed various categories of preys in water bodies of Azagny National Park due to the great diversity of aquatic species and food resources availability (Koné et al., 2021; Konan et al., 2021). In fact, it has been widely shown that several fishes exhibit opportunistic feeding behavior (Saikia, 2015), and the diet can change according to sampling sites, seasons, specimen size and other factors (Morte et al., 2001; Castillo-Rivera, 2013; Konan et al., 2014a). Thus, this present study aims to describe dietary composition of both estuarine species inhabiting in mangrove forests of Azagny National Park.

Material and Methods:-

Study area

The Azagny National Park (ANP) is located in the Southern part of Côte d'Ivoire, in Grand-Lahou and Jacqueville departments, between latitudes 5°9'N and 5°17'N and longitudes 4°47' W and 4°57'W (Figure 1). The climate is sub-equatorial, with an average rainfall of 1,650 mm and an average annual temperature of 26°C (Gnangbo et al., 2016). The ANP is surrounded by several water bodies including Bandama River Estuary, Azagny Channel and Ebrié Lagoon. The Azagny Channel is 18 kilometers long and it was dug to reach by navigation, Bandama river, Grand-Lahou lagoon and Atlantic Ocean. The ANP is home to important diversity of animal species such as primates, reptiles, birds, invertebrates and fish (Kouamé et al., 2010). The vegetation along water bodies is dominated by mangrove forests and the main species are *Rhizophora racemosa* and *Avicennia germinans* (Gnangbo et al., 2016). Three sampling stations S1, S2 and S3 were defined according to mangrove forests density and they are located near Noumouzou, Amessan-Nguessandon and Azagny villages, respectively. The stations S1 and S2 are located on Azagny Channel, and S3 on Ebrié Lagoon (Figure 1).

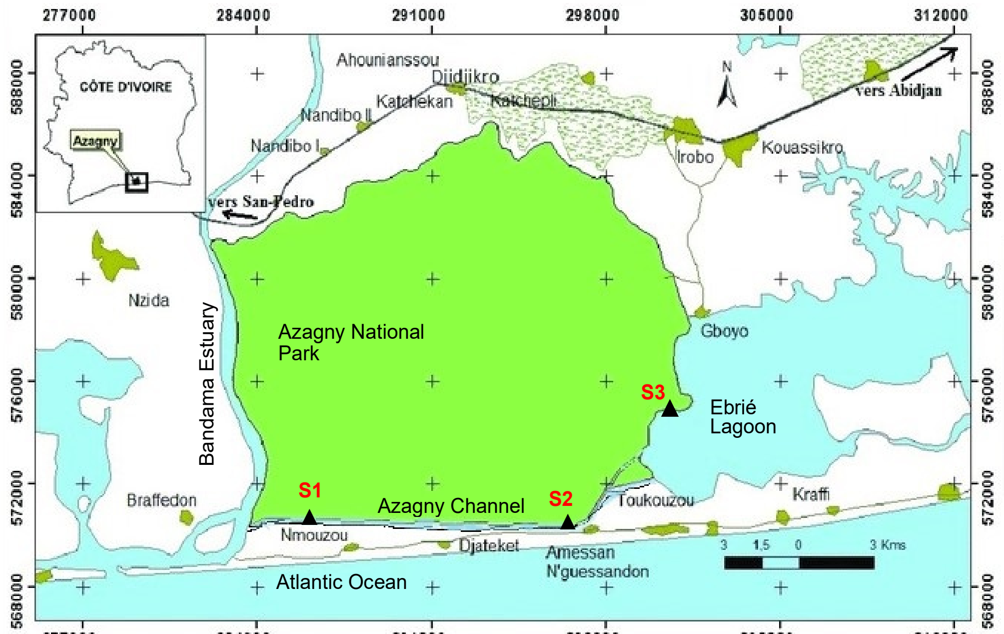

Figure 1:- Map of Azagny National Park (Côte d'Ivoire) showing sampling stations (▲).

Fish sampling and stomach contents analysis

Fish were caught monthly between March 2019 and February 2020 using monofilament nets with mesh sizes of 15, 20, 25, 30 mm and traps. After specimen identification according to Paugy et al. (2003), individuals were dissected and their stomachs were removed and stored in in a pill box containing 5% formalin. In the laboratory, stomachs were opened and content was filtered through a series of sieves with 500, 250 and 100 µm mesh sizes. Food items in the stomachs were placed in a petri-dish and segregated to study the food composition. Prey items were identified by using binocular and microscope according to Elouard (1981), Dejoux et al. (1981), Tachet et al. (2003) and Moison (2010). Then, items were counted and weighed for the determination of dietary indices. For small preys (plankton), where it was not possible to obtain the weight, the volume was measured by water displacement using graduated cylinders (0.1 ml) (Lalèyè et al., 1995).

Diet analysis

The frequency of occurrence (%F), numerical percentage (%N) and weight percentage (%W) and volumetric percentage (%V) were employed for the stomach contents analysis (Young et al., 1997); Konan et al., 2014b). To reduce bias, dietary importance of food items was determined using the Relative Importance index (RI) by the following formula (George and Hadley 1979, Hyslop 1980):

$$RI = (\%N + \%W + \%F) / \Sigma (\%N + \%W + \%F) \times 100.$$

Food items were classified into three categories: accessory preys, RI < 10%; secondary preys, 10% < RI ≤ 50%; main preys RI > 50% (Georges and Hadley,1979).

The vacuity index (VI) is expressed as the number of empty stomachs divided by total number of stomachs multiplied by 100 (Hyslop, 1980; Konan et al., 2014b). In this study, the stomach is considered full when the stomach has at least 1/3 or 2/3 of contents filled with food while it is empty when it does not contain food or it contains totally digested food. The interspecies dietary overlap has been calculated with the Morisita–Horn Index (Horn, 1966; Smith and Zaret, 1982). The trophic overlap was considered low (0.00–0.29), moderate (0.30–0.59), or high (≥ 0.60) following Langton (1982). The diets among both species were compared by a chi-square analysis (Sokal and Rohlf, 1981). The RI values obtained for three sampling stations were compared by One-way Anova (Alvim et al., 1998). Contingency table analysis was applied to determine the differences between common preys obtained in stomach contents of both species (Lalèyè et al., 1995). All analyses were performed using Past 3.21 software (Hammer et al., 2001), with significance level for all tests set at $p < 0.05$.

Results:-

Dietary composition

A total of 117 stomachs of *C. zillii* were examined and 21 were empty, with a vacuity index (VI) of 18%. In C. nigrodigitatus, 11 were empty in all 80 stomachs examined, for a VI of 13.75%. The diet of *C. zillii* included 8 prey categories which are insects, fish (Diptera), molluscs (bivalve), macrophytes, phytoplankton, zooplankton, eggs (unidentified) and detritus (Table 1). Macrophytes consisted of leaves, stems, seeds and plant debris. Phytoplankton included Diatoms and Algae and zooplankton consisted of Cladocera and Rotifera. Sediment (mud and sand) was found in stomach contents. Among item preys, macrophytes were the most frequent (%F = 43.13) followed by sediments (%F = 15.23). The most numerous items were eggs (%N = 41.07) and those with the highest volumetric percentages were macrophytes (% V = 37.59) and fish (% V = 33.75). The Relative Importance index (RI) analysis showed that macrophytes (34.65), eggs (15.61) and fish (15.56) were secondary preys while other prey were accessory (Table 1).

The food spectrum of *C. nigrodigitatus* was composed of 7 prey categories including insects, annelids, crustaceans, gastropods, fish, macrophytes and detritus (Table 2). Insects belong to 3 orders, Diptera, Odonata and Hemiptera; Annelids included Polychaetes (Nereididae) and Oligochaetes (Tubificidae) and Crustaceans included shrimps, crabs and gammarids. Sediment was also found in stomach contents of *C. nigrodigitatus*. Macrophytes (%F = 39.02) and detritus (%F = 15.45) were the most frequent in stomach contents. For the numerical percentage, Nereididae (%N = 39.97) and Diptera (%N = 33.85) were the most dominant. On the other hand, macrophytes (%V = 57.85) and Nereididae (%V = 20.65) exhibited the highest volumetric percentage. The RI values indicated that macrophytes (37.91), annelids (21.71) and insects (19.8) were secondary preys and other prey were accessory (RI < 10).

The common preys to both species were insects, fish, molluscs, macrophytes and detritus. Phytoplankton, zooplankton and eggs were only observed in stomachs contents of *C. zillii* while annelids and crustaceans were only found in *C. nigrodigitatus*. The comparison of general diet of both species showed significant differences (Chi-square = 57.28; $p < 0.05$). Contingency table analysis was applied to test the differences in RI values of common preys between species. This test showed significant difference between *C. zillii* and *C. nigrodigitatus* in the following common preys, insects (Chi-square = 4.88; $p < 0.05$) and fish (Chi-square = 14.46; $p < 0.05$). Morisita–Horn index between both species based on RI values of prey items indicated a moderate similarity (α =0.54).

Table 1:- Dietary composition of *Coptodon zillii* from mangrove forest of Azagny National Park (Côte d'Ivoire) expressed as frequency of occurrence (%F), numerical percentage (%N), volumetric percentage (%V) and Relative Importance index (RI).

ITEMS	%F	%N	%V	RI
Insects				
Diptera	8.81	11.68	6.89	9.13
Fish	7.95	4.99	33.75	15.56
Molluscs				
Bivalve	2.6	3.33	1.48	2.47
Macrophytes	43.13	23.23	37.59	34.65
Phytoplankton				
Diatoms	2.60	1.25	3.66	2.51
Algae	3.25	7.06	3.90	4.74
Zooplankton				
Cladocera	1.98	3.74	3.27	3.00
Rotifera	1.95	0.42	2.35	1.57
Eggs	2.58	41.07	3.19	15.61
Detritus	4.76	3.23	3.93	3.97
Sediment				
Mud	15.23	—	—	—
Sand	5.16	—	—	—

Table 2:- Dietary composition of *Chrysichthys nigrodigitatus* from mangrove forest of Azagny National Park (Côte d'Ivoire) as frequency of occurrence (%F), numerical percentage (%N), volumetric percentage (%V) and Relative Importance index (RI).

ITEMS	%F	%N	%P	RI
Insects				
Diptera	12.2	33.85	5.29	17.11
Odonata	0.81	0.23	0.02	0.35
Hemiptera	4.07	2.24	0.71	2.34
Annelids				
Nereididae	8.13	39.97	13.84	20.65
Tubificidae	0.81	2.01	0.37	1.06
Crustaceans				
Shrimps	4.07	1.30	3.64	3.00
Crabs	3.25	0.48	15.52	6.41
Gammarids	0.81	0.35	0.03	0.40
Molluscs				
Thiaridae	0.81	0.23	0.79	0.61
Fish parts	1.63	0.23	0.31	0.73
Macrophytes	39.02	16.87	57.85	37.91
Detritus	15.45	2.24	1.62	6.44
Sediment				
Mud	4.07	—	—	—
Sand	4.87	—	—	—

Spatial variation of food patterns

The spatial variation in the diet of both species were shown in figures 2 and 3. In *C. zillii*, Macrophytes were dominant in all stations, with RI values of 40.35, 42.06 and 37.17 in S1, S2 and S3, respectively. In S1, only 3 items were found in stomachs contents: macrophytes, phytoplankton and eggs while all items were found in stomachs of S3. According to RI values, macrophytes were secondary prey in all stations, phytoplankton were secondary prey in S1 (32.16) and S2 (15.30), eggs were secondary prey in S1 (15.37) and S3 (16.36) and fish were secondary prey in S2 (11.89). The comparison of food composition of *C. zillii* between sampling stations showed no significant differences (Anova, $F = 0.001$, $p > 0.05$).

In *C. nigrodigitatus*, macrophytes were the most abundant items in S1 (23.77) and S3 (41.34) while annelids dominated stomach contents in S2 (44.12). Gastropods were only found in stomachs in S1 while fish prey were observed in S3. In all stations, macrophytes, insects and annelids were secondary prey (RI>10) while gastropods, detritus and fish were accessory prey (RI<10). Crustaceans were more dominant in stomach contents in S1 than other sampling stations. Likewise, the spatial variation of dietary composition of *C. nigrodigitatus* showed no significant differences (Anova, $F = 0.002$, $p > 0.05$).

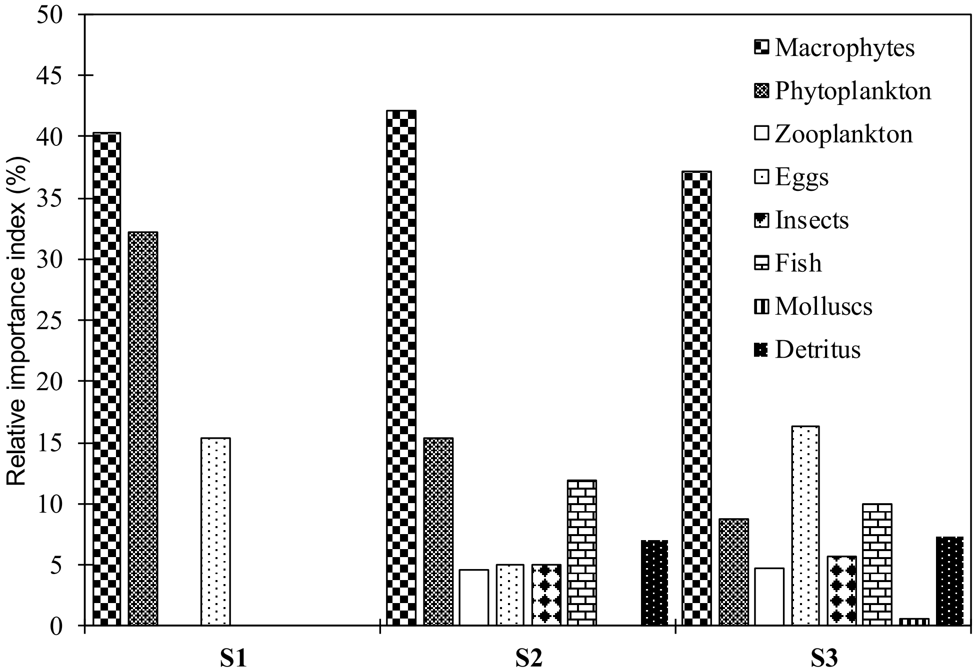

Figure 2:- Food composition variation of *Coptodon zillii* from Azagny mangrove forests according to sampling stations (S1, S2, S3).

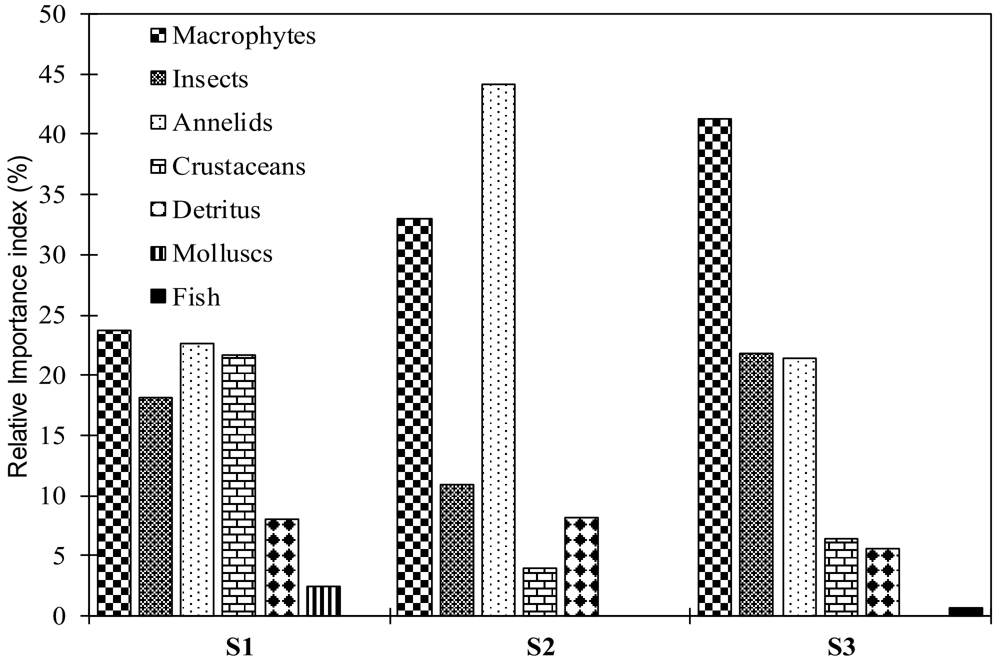

Figure 3. Food composition variation of *Chrysichthys nigrodigitatus* from Azagny mangrove forests according to sampling stations (S1, S2, S3).

Discussion:-

This work showed that *C. zillii* consumed a wide range of food items categorized into 8 groups with the dominant prey being macrophytes, eggs and fish. These results showed that this species is omnivorous in its diet with a macrophage tendency. Similar results were obtained in Lake Ayamé by Shep et al. (2013) that indicated an omnivorous diet composed of six prey categories with macrophytes and Diptera were the main prey. Agbabiaka (2012) reported that the omnivorous diet in C. zillii and the stomach contents largely contain algae, macrophytes, detritus and insects in Otamiri River. An herbivorous diet that is mainly composed of macrophytes, detritus and phytoplankton has also been indicated in Lake Ziway (Dadebo et al., 2014). However, the diet was invertivorous and composed mainly of diptera and zooplankton in Lake Kinneret (Israel) (Spaturu, 1978). The results tend to show that *C. zillii* fed on all available preys in its living environment.

The stomach contents of *C. nigrodigitatus* were categorized into seven item groups with the main prey were macrophytes, annelids and insects. Other food items were crustaceans, molluscs, fish parts and detritus. This allows to indicate an omnivorous diet with a preference for macrophytes. There are some differences between the present study and previous studies as related to the feeding habits of this species. For example, an omnivorous diet (with a carnivorous tendency) has been indicated in *C. nigrodigitatus* in south-Benin lagoons (Lalèyè et al., 1995). Stomachs contained six prey categories such as fish, molluscs, crustaceans (Entomostraceans and Malacostraceans), insects, macrophytes and detritus. Likewise, the diet was also omnivorous in Lagos Lagoon with six prey categories, with algae, diatoms and crustaceans as dominant prey (Kuton and Akinsanya, 2016). In contrast, some authors reported a detritivorous diet in the Pra River Estuary of Ghana (seven item groups with an absence of macrophytes) and the Cross River Estuary of Nigeria (six item goups) (Ndome and Udo, 2018 ; Okyere and Boahemaa-Kobil, 2020). The omnivorous or detritivorous feeding behavior of C. nigrodigitatus with preferences for animal or vegetable prey depending on the aquatic environment also showed the opportunistic feeder. This opportunistic behavior has been indicated by several authors in some fish as *Cyprinus carpio* (Philip, 2006). Indeed, this author stated that when animal based food is limited, *C. carpio* was forced to eat the seeds of water grown plants such as rice and the seeds of wheat, oat and maize. It is therefore likely that accessory prey such as planktonic organisms, mollusks and detritus were consumed by both species when dominant prey was not available.

The macrophytes abundance in dietary composition of both species may be related to canopy cover. Indeed, the leaves, stems and fruits of mangroves fall into the aquatic environment under the action of wind and rain and constitute an important food resource (Canning et al. 2019). In fact, according to Death and Zimmermann (2005), allochthonous litter sources dominate in the forested streams but autochthonous algal production dominates in the grassland streams. Similar observations were obtained in *Clarias buettikoferi* where an abundance of macrophytes was observed in stomachs contents (Konan et al., 2014b). In this study, the number of prey category observed in stomachs of both species was higher than those reported by previous works (Spaturu, 1978 ; Lalèyè et al. 1995; Agbabiaka, 2012; Ndome and Udo, 2018), which confirms the great availability of food resources in mangroves areas (Abuodha and Kairo, 2001 ; Mazda et al., 2002). The low values of vacuity index (13.75% and 18% in C. nigrodigitatus and *C. zillii*, respectively) seem to confirm an intense feeding activity in this study area.

The present study also indicated the presence of sediment in stomachs of both species. Thus, the high frequencies of mud, sand and benthic macroinvertebrates (insects, molluscs, annelids) tend to show benthophage behavior as indicated by several works (Shep et al., 2013; Ndome and Udo, 2018). Observation of common prey such as macrophytes, insects, molluscs, fish and detritus in both species helps explain the moderate dietary overlap. However, significant differences in the diet may be related to different ecological niches and different feeding behavior. In both species, although some prey (i.e molluscs) were observed in a single station, the spatial variations in diet were small and differences were not significant. This may be explained by little variation of aquatic organism diversity and similar abiotic parameters in the three stations. Indeed, Konan et al. (2021) showed little variation in benthic macroinvertebrate assemblage in three sampling stations of Azagny Channel.

Conclusion:-

This work indicated the dietary composition of *C. zillii* and *C. nigrodigitatus* from mangrove forests in Azagny national Park. Both species exhibited an omnivorous diet with a preference for macrophytes. The presence of sediments and the benthic macroinvertebrates abundance showed benthophage feeding habits. The large number of prey categories showed a high availability of food resources in this study area. Although several prey such as macrophytes, insects, molluscs, fish and detritus have been found in stomach contents of both species, differences in diet were significant, reflecting different strategies in prey capture. The present study of natural diets of these species provides further support on practices of aquatic management, especially agriculture, aquaculture and conservation.

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