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Global lessons and information to assist with monofilament gill net management in Ghana

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Cover Photo: *Fishermen repairing their nets*

Cover Photo Credit: *Coastal Resources Center – Ghana*

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Monofilament nets in Ghana

Ghanaian fishers have a long history of rapid innovation and adoption of technologies that improve the efficiency of fishing operations – the diverse gill net sector is no exception. Gill netting in Ghana (as elsewhere) began with cotton or hemp nets, and a major technological change[1] has been the progression among several net types from cotton to woven nylon multifilament nets and then to monofilament nets [2]. A multifilament net is one where each 'string' or filament making up the net mesh is a thin braided or twisted twine (like very thin rope), while a monofilament net is one where the net is made of single strands of a synthetic material that looks like a stand of modern fishing line. Polyamide (i.e. nylon) became the first synthetic material to replace cotton or hemp for fishing gear construction[2]; initially as multifilament and later as monofilament. Following the adoption of monofilament nets, thinner filaments[3] have been adopted over time [5] to further improve catching efficiency [4]. Globally the conversion from multifilament to monofilament nylon netting occurred in some places in the early 1970s [3], while fishers in Ghana report rapid uptake in the 1980s.

Why fishers switch to monofilament?

Reasons for fishers changing from multifilament to monofilament nets include perceptions of higher catch efficiency, lower relative cost and ease of use. Scientific trials indicate that monofilament nets are often twice [3, 8] to four times [8][4] as efficient as multifilament nets. That is, for the same net length and mesh size, a monofilament net will catch 2-4 times as many fish as a multifilament net. The main reasons for this are the low visibility of nets in the water [3], and the different way the nets catch fish; fish in the monofilament nets are mostly gilled (caught around the gills with their head through the net) whereas those in multifilament nets are generally trapped by tangling [10].

However monofilament is not always more efficient and it seems that fish size and shape as well as water characteristics and net colour may alter the relative catch rates of the different net types. For example, trials in a lake in Nigeria showed that multifilament gillnets generally caught higher quality and more fish (as fish entangled more easily) [6].

Another study showed that monofilament netting was more efficient only for certain marine species [3]5. Where catch rates are very high or 'soak times' (time the nets are left in the water on each fishing occasions) are long, rapid saturation6 of monofilament nets may reduce the relative efficiency compared to multifilament nets[9]. Hɛn Mpoano is currently conducting fishing trials to understand the differences in catch rates in the specific situation of near shore gill netting in Ghana.

The relative cost of monofilament and multifilament nets clearly influences their use in Ghana. Monofilament nets are cheaper than multifilament for small mesh sizes, while the opposite is true

[1] Other technological advances include locating schools with echosounders or spotlights at night, outboard motors, vehicles to launch and retrieve craft etc [1].
[2] In India.
[3] In inshore fisheries monofilament of 0.20/0.23mm diameter used was replaced by 0.16mm [5].
[4] Citing Molin 1953
[5] Citing Pristas and Trent 1977
[6] Net saturation occurs when a lot of fish are caught, making the net visible to other fish and reducing catch rates

for larger mesh sizes (Table 1). It is not surprising then that the greatest uptake of monofilament in Ghana has been among the 'tenga' fishers – a gear comprised of multiple bundles of small mesh of different sizes. Among fishers who use larger mesh sizes (e.g. Ashekon nets) multifilament nets often dominate.

Table 1 Mesh sizes employed in two main bottom set net fishing methods in Ghana. Nets prices provided for mesh size for monofilament and twine netting [7].

Mesh size inches	Fishing Method	Price (cedis) per bundle (100 yards)	
		Mono filament	Twine
1 1/2"	Tenga	75	100
1 5/8"		70	90
1 7/8"		70	90
3"	Ashekon	110	80
3 1/2"		110	80
3 5/8"		110	80
3 7/8"		110	80
4"		110	80

While a disadvantages of nylon nets is their relatively high sensitivity to ultraviolet rays [5][7], monofilament nylon nets were less susceptible to degradation due to exposure to sunlight than multifilament nylon[8][5][9]. Other advantages of monofilament nets over multifilament nets is that they incur less damage, are fished more easily, tangle less and can be set and retrieved faster [8][10].

Monofilament nylon line can be made more or less visible in the sea by using coloured dye. Undyed line nets are least visible when perpendicular to the sea surface but can have high glint when parallel to it [11]. The glint is reduced by pale dye colours that remove a proportion of the green light, but the correct colour for a net depends on the depth of fishing and time of day due to different light effects [11]. One study showed that net visibility differs between species due to differing spectral sensitivity and visual acuity [3][11].

Disadvantages of monofilament net and issues for management.

Commonly stated disadvantages to fishing with monofilament versus multifilament nets is that they take up more space in the fishing boat [1] and in some cases are said to be less durable overall and require more frequent repair than multifilament mesh [1]. Thinner twines that are preferred for higher catch rates, are less resistant to weathering than thicker twine, and nets made of thinner twine need frequent replacement[12] [5].

[7] Citing Molin 1959
[8] After 180 days monofilament nets retained 64.6% of their initial breaking strength whereas multifilament retained only 46.6% [5]
[9] Citing Alsayes et al. 1996
[10] Citing Pristas and Trent 1977
[11] Citing Steinberg 1964
[12] For example nets that were made of twine 0.16mm in diameter may for only last for 6–9 months [5].

Bycatch

Bycatch, or the capture of non-target species, is a global concern particularly from gillnet fisheries, as bycatch species can include protected or endangered species, immature and undersize fish or species targeted by other fisheries [2]. For example in South Africa while gillnet catches comprise a fairly small proportion of species targeted by shore anglers[13], the high catch rates of gill nets means that the total catch of these species is comparable to that caught by shore anglers [12]. At-sea observations of small-scale fisheries in Mexico showed that compared to other gears (i.e. drift gillnets, lobster traps and fish traps) set gillnets had the highest overall impact on both non-target species and habitat[14], with discard rates higher than most industrial fisheries [13].

Ghost Fishing

If nets are lost or discarded they may maintain the ability to 'catch' for up to several years, causing unaccounted for fishing mortality – this is referred to as "ghost fishing". Entangled species may be those targeted by net fishers[15] or may be non-target species. Additionally ghost nets can cause habitat degradation or interfere with normal fishing and may even be a major cause of further lost gear [18].

Ghost nets can continue to catch fish and other organism for several months [18]. A study in Turkey showed that ghost fishing continued by monofilament gillnets for 106 days and by multifilament nets for 112 days. Total catch rates of monofilament gillnets were significantly higher than multifilament gillnets probably due to higher visibility of multifilament nets [17].

Although ghost nets can continue to catch fish, their catching efficiency decreases rapidly even after the first few weeks (but changes specific to sites, season and nets structure). In one study, nets continued to catch fish for 15 to 20 weeks but catches dropped sharply in the first few weeks and gradually thereafter [18]. In another study catch rates reduced by around 80% during the first 3 months [17][16]. In a third study, after 6 months the effective fishing areas of nets had reduced by 55% (monofilament) and 63% (multifilament) and nets were close to collapse [17]. The loss of the nets fishing ability is due to "changes in net shape, increasing net visibility (e.g. due to fouling), decreasing net height and effective fishing area, and increasing wear and tear" [18].

Global Experience from Managing Net Fisheries

Case studies from across the world highlight measures or restrictions that can be applied (sometimes concurrently) to net fisheries to avoid conflicts with other fisheries, to reduce the catch of non-target or juvenile species, to control fishing capacity, to help recover fish stocks and/or to keep the fishery operating at sustainable levels. Multiple issues can be addressed and experienced in the application of management measures.

[13] considered bycatch as it was illegal for gillnet fishers to target these species

[14] For example discard rates were 34.3% by weight of total catch and an estimated 19.2% of *Eisenia arborea* kelp and 16.8% of gorgonian corals damaged or removed within 1 m of the net path [13].

[15] For example monkfish caught by lost nets in the Cantabrian Sea totalled to the equivalent of 1.46% of commercial landings (Sancho et al. 2003 in [17]).

[16] Citing Tschernij and Larsson 2003

Net Limits – mesh size, net length and number

A management issue with monofilament nets is that their introduction greatly increases the effective effort of a given length of net, often compromising management systems that have developed around less efficient nets. Small-mesh nets, of sizes generally ineffective when built in multifilament twine, are often an issue, and the ability to catch juvenile fish a major problem for fishery managers.

The effectiveness of nets is influenced by mesh size, net length and number of nets – all factors that can form part of a management system. Gillnets catch fish of certain size, as a function of mesh size and fish shape and size[17]. For any mesh, there is generally[18] a lower size limit below which fish are small enough to pass through the mesh and an upper size limit above which fish do not become enmeshed [9][19]. In gillnet fisheries restrictions to certain mesh sizes can help to avoid the capture of juveniles [2][20] or non target fish [2][21].

Between upper and lower limits, the size range of fish caught can be predicted with some accuracy [9]. For example, trials from the Jamaican surface floating multifilament gill net fishing found length-mesh selection relationships several species [9]. This information, alongside economic and biological information (e.g. size of onset of maturity) can be useful to managers in selecting appropriate mesh size limits or ranges.

To limit total effort in the Western Cape gillnet fishery, permits were used in conjunction with restrictions on the maximum length and numbers of nets; however restrictions on nets were seldom enforced effectively [1]. In Italy a net length limit (proposed due to political pressure) was ignored as if it had enforced the fishery would not have been profitable [19].

Managing bycatch

Levels of bycatch are affected by net properties and there are modifications to nets that can reduce incidental catch. Many commercial fisheries including longline, trawl and net fisheries have enforced modifications to fishing gear via legislation that reduce bycatch levels.

Mortality of diving birds can occur in gillnet, drift and demersal gillnet fisheries operating in coastal and high seas areas [14][22]. Three main types of efficient bird bycatch mitigation methods have been identified, but these can also result in lower catch rates of target species [14][23]. These include visual alerts to increase the visibility of the nets e.g. by dyeing the nets with an opaque colour [14][24] which can increase by catch of birds and cetaceans, however, increased visibility also leads to reduced catches of targeted fish. A second type of mitigation method is attaching an acoustic alert to gillnets that signal in the hearing frequency of seabirds

[17] T*hickness, composition and colour of net twine, hanging ratio and method of fishing may also affect selectivity (Dalzell 1996* in [2])
[18] Some small fish can be captured if they have spines for example [2].
[19] Citing Hamley I975
[20] Citing Milton et al. 1998 - For example in the Papua New Guinean barramundi fishery where mesh size limits are combined with seasonal restrictions
[21] Citing Ley et al. 1999 – For example in the Australian estuary *L. Calcarifer* estuary fishery
[22] Citing Melvin et al. 1999, Trippel et al. 2003, Zydelis et al. 2009
[23] Citing Melvin et al. 1999, 2011, Sullivan et al. 2006a,b
[24] Citing Melvin et al. 1999, Trippel et al. 2003

[14][25]. The third method is subsurface setting or setting gillnets at depths greater than birds can dive [14][26].

Gillnets can result in significant bycatch of cetaceans [15]. Increasing the sound reflecting properties of gillnets can reduce the catch of echolocating cetaceans [14][27].

Small-scale, coastal, passive net fisheries are one of the largest threats to some sea turtle populations [16]. Reducing turtle bycatch is possible via gear technology approaches for gillnets (and trammel nets). Measures include increasing gear visibility to through illumination and line materials; reducing net vertical height; increasing tiedown length or eliminating tiedowns; incorporating shark-shaped silhouettes; and modifying float characteristics, the number of floats or eliminating floats [16].

In South Africa political pressure from shore anglers resulted in a number of measures and restrictions placed on gillnet fishers to avoid conflict between the two fisheries; for example the landing of line angler target species in nets was limited to 10 fish per day [2]. However, these bycatch restrictions were found to be unrealistic, were often ignored and were not supported by net fishers [1]. Many net fishers had traditionally caught valuable line fish and the financial rewards of keeping large line fish far outweighed the low risk of a fine. Additionally mortality of the bycatch was often unavoidable as fish were injured or killed during entanglement [2].

Environmental lobbyists claimed that the Italian drift net fishery for swordfish and tuna was responsible for high levels of bycatch of sea mammals, turtles and birds. Mangers were pressured to take measures leading to an (unsuccessful) buyback process that spanned over 15 years – discussed further in the buybacks section [19].

Closed Areas or Zones

Closed areas or fishing zones can help *to reduce competition and conflict between user groups and/or limit the impact of gillnetting in ecologically "sensitive" areas, or on vulnerable species aggregations* [20].

For example closed areas were used (in conjunction with closed seasons) to avoid conflict between net fishers and anglers in USA [2][28]; restricted areas were effective in reducing game fish bycatch also un USA [2][29]; closed areas (in conjunction with gear restrictions) were used in Kosi Lakes, South Africa to decrease the proportions *of non-target species, decrease conflict with recreational anglers and traditional trap-fishers and limit interference with fish migrations* [2][30]. And in South Africa commercial net fishers were restricted to specific areas to avoid conflict and bycatch interactions with the line fishing industry [20].

Permits

In 1974 compulsory licensing of gill and beach-seine nets came into place In Western Cape,

[25] Citing Melvin et al. 1999
[26] Citing Melvin et al. 1999 citing Hayase & Yatsu 1993
[27] Citing Trippel et al. 2003.
[28] Citing Moore 1980
[29] Citing Quinn 1980
[30] Citing Kyle 1999

South Africa [1][31]. Most permit-holders operated in the fishery part time i.e. many fishers used net fishing to supplement their income; for example from the pelagic fishery, which usually closed over the summer when net fishing would peak [1]. Management encouraged part-time participation in net fishing and awarded permits preferentially to applicants who were part time or retired fishers. Unfortunately, this policy amounted to effort subsidization to the disadvantage of those who were attempting to operate as full-time commercial net fishers [1][32]. Also political pressure was applied to issue permits to *all* those that applied resulting in the fishery remaining essentially "open access" (aside from some closed areas) [1]. As a result the Western Cape net fishery operated at levels greater than optimal, the resource was overexploited and a second round of effort reduction was recommended [1][33] via reductions latent and "recreational" fishing [12]. To reduce effort in a fair and equitable fashion it was recommended that current and potential new permit-holders should be assessed on an individual merit basis (Box 1).

Net Ban or Moratorium

Several net fisheries have employed bans or moratoriums to address issues of political pressure, conflict with other fishing sectors, concerns over the long term viability of the fishery or for conservation reasoning. For example, in 1984 on the West Coast of South Africa the gillnet fishery

BOX 1 – An example from South Africa of criteria to reduce fishing effort in a fair and equitable fashion; Direct quote [1]

To receive a permit fishers had to:

- be able to prove some past involvement in the net fishery, either having worked as crew for current permit-holders or having operated their own equipment. This would ensure that they have the skills and experience necessary to be successful net fishers;
- have the financial means to afford the initial capital outlay for their equipment (if they do not already have access to it) and be able to afford the daily running and maintenance expenses;
- motivate that they have the time available, in that they do not have other work or fishing obligations, and the economic need to net fish regularly;
- demonstrate that they have the business skills required to fish in an economically viable manner;
- show that a market is available for the fish they catch or provide information on how they process and market their own catches;
- demonstrate a knowledge of and respect for the regulations relevant to net fishing and a concern for the sustainability of the resource.

(targeting galjoen) was banned in response to recreational angler complaints and conservation and stock management concerns [12][34]. A moratorium has been in place since 1994 Virginia's river (USA) fisheries for American shad, declared in response to declining harvest and catch rates (note this fishery historically employed multifilament nylon nets and in modern times monofilament nylon gill nets) [21]. To avoid the extinction of a cetacean species due to bycatch, the government of Mexico took the politically unpopular[35] step of banning the use of

[31] Citing De Villiers 1987
[32] De Villiers 1987, Stander 1991
[33] Citing Anderson 1986, McManus 1996
[34] Citing Bennett 1988
[35] There was a history of civil unrest in the region when attempts were made to implement fisheries regulations

gillnets [15].

Case studies of gill net bans

A moratorium can remove fishing pressure to allow recovery of stocks and can provide the opportunity to examine historic and recovery data [21]. However there can be political, social and economic impacts of bans and if not managed well this can even result in low or no overall reduction in fishing pressure and increased conflict between fishers and managers.

In Mexico a generation of net fishers had, for the most part, not been regulated and therefore a ban (prompted by bycatch leading to species extinction) was perceived as taking away their right to a livelihood. In the short term, economic compensation was required for fishers who lost their income. In the longer term, alternative methods of fishing (that do not result in similar bycatch issues) will need to be developed and/or fishermen must be provided alternative livelihood [15]. Despite the ban on gill net fisheries, significant levels of illegal fishing continues: equivalent to two-thirds of the legal fishing effort [15].

Concerns for bycatch largely drove a ban and buy back scheme for the Italian drift net fishery. The buyback scheme included reconversion (an option to use gear other than drift nets) or permanent withdrawal; where allowances or compensation were of different values. The social impacts and effects upon employment were severe, however the ban and the buyback programme failed to result in a decrease in fishing; it shifted effort from Italian fishers to international fishers that were still able to exploit the same stocks and also shifted Italian fishers into coastal areas that were already over exploited and so fishers also experienced negative financial impacts [19]. The process was driven by politics rather than biological, social and economic impact data and resulted in an expensive programme that with overall negative effect for the stock and fishers [19].

A ban on exports of live fish from Palawan, Philippines was met with furious lobbying. The ban was seen to be ignorant of the needs and dignity of the poor and was viewed as an example of unjust governance. Lobbying was followed by negotiations with decision makers and the ban was eventually overturned [22]. Many fishers fear a future ban on the live reef fish trade and are uncertain of their coping strategies as there are limited alternative livelihoods [23].

In Florida, USA a ban was placed on the use of commercial entanglement nets and 1500 families had to quickly change fishing gear or leave the fishery. The government aimed to ease the transition with direct assistance provided through a net buyback programme and indirect assistance to support job retraining and the unemployed. However it seemed that poor management of the expensive scheme may have resulted in increased pressure on resources due to a shift in focus to other species. Additionally there were long lasting mental health and other social impacts on fishing families and communities [24].

Buy-Backs

Globally the need for buybacks, sometimes called decommissioning schemes, generally arises due to poorly structured property rights, particularly in situations of open access or no property

rights [25]. Buybacks, can be used for many reasons[36] but in general are used to reduce over-capacity that has lead to overexploitation or economic inefficiency [26]. The transition must operate in or lead to a system of rights based management or limited access [27].

Most buyback programmes will include purchase of vessel or licences and permits, however in some cases may only involve the purchase of gear [28]. For example in Mexico a buyback scheme was employed to help address the problem of porpoise bycatch from gillnets. To avoid extinction of this species of porpoise the government made the decision to enforce a gillnet ban and then followed up with arrangement for buyback of licences and finding alternatives for fishers while also enforcing the ban [15].

This highlights two important points about buybacks. Firstly calculating appropriate economic (or other) compensation is an important but difficult task. It is particularly difficult when a fishery or many fishers are operating illegally [15]. Setting the level of compensation or buyback price requires careful planning and detailed information about the economic costs and gains in a fishery (i.e. per fisher, per vessel or per licence). Financing that scheme also requires careful planning. Detailed lessons regarding such systems can be found in published reports [25, 29].

Secondly, the reduction in effort due to buy backs are only temporary unless a long term plan and measures are put in place. For example without sufficient long term measures fishers may re-enter the fishery, or remaining fishers will continue to invest, new technology will be adopted, nets may get longer or fishers may simply fish for longer [30]. If these things happen, the result of reduced fishing capacity that was achieved from the buyback will be lost [29].

It is also important to consider that there will be different impacts of buybacks on different fishers, including short term advantages to fishers remaining in the fishery, who may therefore increase their investment or fish more. Also if planning is poor (due to poor information for example) the buyback scheme might result in the exit of fishers that were least efficient or fished the least – and therefore the scheme would not result in a very big reduction of capacity for the funds spent. Also there are different impacts on who gains and who loses; for example often crewmembers do not gain or gain little from buy back schemes [29].

If an alternative for fishers leaving or reducing their capacity in a fishery is unavailable or offers lower net benefits, then a one-time payment of compensation could be used but may be insufficient because fishers will be incurring an ongoing net cost [31]. For example buybacks can be used to facilitate the replacement of harmful gear with biodiversity friendly gear [29]. But fishers replacing one gear with another less harmful, but also less efficient gear (e.g. replacing one hook with another less prone to bycatch), will be experiencing less effective fishing while also delivering a conservation benefit or a public good[37] every time they fish [29].

In the Mexico net fishery example, the government created a voluntary one-time compensation

[36] (i) Directly increasing economic efficiency (ii) Modernizing fleets and adjusting their structure and composition (iii) Facilitating the transition from fisheries with overexploited stocks and overcapacity to private or common rights-based conservation and management (iv) Providing alternatives when rights-based management is infeasible (v) Providing disaster or crisis relief (vi) Addressing compensation and distributional issues (vii) Conserving common resources underlying a fishery (viii) Conserving biodiversity and ecological public goods

[37] There are situations where delivering a public good may be seen as cause for extra compensation or incentive

program to fishers who chose to give up their gillnet permits (note the programme only dealt with legal fishers); either as a buyout for fishers willing to stop fishing or a "switch-out" with a lesser payment, for fishers willing to switch to a new fishing method and gear that had been trialled by the fisheries institute [15].

Without careful planning expensive buyback programmes may have negative consequences [19, 24]. Employing some clear design principles (Box 2) can help to lead to positive impacts on fisheries and for fishers from buyback schemes.

Box 2 - Design Principles for Buyback Programmes
Direct quote [29]

1. The buyback programme should set clear goals and objectives
2. The buyback programme requires a clearly defined scope i.e. which gear types and fisheries, vessel size classes, geographic areas, full- or part-time or commercial or recreational, vessels / licences
3. Three critical preconditions that must be fulfilled for an effective buyback programme.
    (i) Proper registration of licences and vessels creates a well-defined universe of eligible owners and provides well-defined programme boundaries
    (ii) Programme organization and communication between regulators and participants and among participants facilitates success
    (iii) *in situ* measures to prevent new entry of catching power in place of that removed
4. The buyback programme must decide to purchase the capital stock (vessel and/or gear) or the licence, or both. Many vessels hold licences for multiple fisheries and buybacks can create adverse spillover effects.
5. The buyback programme can be voluntary or mandatory.
6. The buyback programme should limit reuse of the purchased vessel, gear or licence, with scrapping of the vessel and/or gear or permanent retirement of the licence the best practice, in order to prevent increases in fishing capacity in the fishery of concern or spill-overs to other fisheries
7. Strong conditions should be placed on reinvestment of buyback funds in the buyback fishery to limit reinvestment or new investment.
8. most buyback programmes entail one-time payments, but some programmes may need recurring payments to cover ongoing opportunity costs and alternative sources of income and livelihood for sellers who are not entirely exiting fisheries altogether, especially when the buyback is oriented to the public goods of conservation and ecosystem services and to developing countries
9. Buyback programmes need to consider conditions on fishing time i.e. Limits on fishing time attempt to manage the flow of capital services and hence utilization of the capital stock, and fishing capacity in general.
10. Some buyback programmes set other conditions on vessels and licences that are purchased.

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