A Simple Model for the Simultaneous Management of Seabird Populations and Discards at Sea

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Abstract

In the past decade the numbers of seabirds worldwide have increased. This has been widely attributed to the increased availability of discards from fishing vessels. As a result, seabirds have over the years learned to depend on this enormous food supply as a major source of food. However, discards are viewed as a loss of potential food for man. In addition, the practice of discarding at sea may in the long-term lead to the loss of marine biodiversity. Coastal managers seek to promote the wise and sustainable use of coastal resources such as fish and seabirds. Because a growing tourist trade depends on seabird sightings, suggestions of reducing the amount of discard raise fears that seabird populations will be adversely affected. The dilemma is how to reduce discards and maintain reasonable sizes of seabird populations. A simple compartment model was developed to track changes in size of tern population through time. Processes modeled include birth, death, immigration and emigration of terns. The model is found to be useful in determining levels of discards that maintain tern populations, and months within a year that discard levels could be reduced without adversely affecting tern population. It is found that a reduction in discards from 75% of catch to 45% of catch between October and December of each year will not adversely reduce tern population size.

Introduction

The past decade has witnessed tremendous increases in the numbers of seabirds worldwide. The success of seabirds has been attributed to the increased availability of discards ('that amount of gross catch that is not directly utilized by man but thrown back into the sea as whole organism' – Saila, 1983) from trawlers at sea. Commercial fishery discards in the North Sea is believed to support an estimated 5.9 million of seabird community (Garthe, Camphuysen & Furness, 1996). Also, Ghanaian ships discard about 75% by weight of their catch at sea, a proportion of which is consumed by seabirds including Common tern, *Sterna hirundo* and Sandwich tern, *Sterna sandvicensis* (Nunoo, 1997). As a result of this discarding practice, seabirds have, over the years, learned to depend on this enormous food supply as a major source of food to sustain increasing populations (Furness, 1982). It is, therefore, not surprising that interest in bird watching has increased, giving a boost to tourism in many coastal nations including Ghana.

Simultaneously, the past decade has seen an upsurge in global concern about the loss to man of a vast potential of valuable food through discarding at sea by trawlers (Andrew & Pepperell, 1992; FAO, 1999). By-catch and subsequent discards inevitably occur in fisheries because most fishing gears and practices are not perfectly selective for the species and sizes targeted and because target species exist in habitats occupied by a wide range of other species. Between 50-90% of the catch by weight of shrimps are discarded at sea worldwide (Alverson *et. al.*, 1994).

FAO (1999) believe that a reduction of post-harvest losses including discards at sea should be achieved in most fisheries. However, there is no simple and quick solution to the discarding problem (Gaston, 1990; Tillman, 1993; Alverson *et al.*, 1994). Rather, several broad management alternatives are currently in place in various fisheries. These include either minimization of by-catch or its better utilization for the benefit of man (IDRC, 1982).

Reducing such waste raises questions of management strategies. For example, if by-catch were to be reduced, how much of a reduction would be acceptable to all stakeholders? Simultaneously, how much of the envisaged shrimp loss accompanying the measure are fishermen and managers ready to accept (Andrew & Pepperell, 1992)? Unfortunately, there are no simple answers to these questions. This is because of conflicts of interest amongst different parties.

Suggestions to reduce discards at sea hinge on the fact that the discarding practice may in the long-term lead to loss of marine biodiversity through deleterious effects on recruitment and biomass of stocks targeted by other fisheries (Nunoo, 1998). On the other hand, it is envisaged that such a reduction in the amount of discards might adversely affect the size of seabird populations. There is, therefore, a need for a wise and adaptive management of both natural resources for maximum benefit to man. This is a major challenge for the coastal manager who seeks to promote the sustainable use of coastal resources such as fish and seabirds.

An available tool to the coastal manager in addressing the issue is ecological modeling. This paper describes an application of a simple modeling process, using computer software, to make predictions necessary for managing an ecological problem. The objective of this model is twofold:

1. To determine the amount of reduction in discards at sea which will not adversely affect seabird populations; and
2. To document the period in a year that such a reduction in discards would have mini mum adverse impacts on seabirds populations.

Materials and methods

The parameters that have a bearing on tern population at any given time were identified. These were entered into the Stella 5.1 software and run over time. The Stella 5.1 software is a general purpose modeling software available from High Performance Systems Inc., USA. The system components and dynamics of material flows were presented as a Forrester diagram (Forrester, 1961 in Haefner, 1996) built into the software.

Subsequently, equations derived from simple assumptions, empirical data and information found in Nunoo (1997) and other published literature was entered into the model. The parameters, terms, equations and simplifying assumptions used in the development of the model are briefly described below. Further, Fig. 1 shows the inflows and outflows into a single state compartment model. It tracks the changes in numbers of terns through time, which is modeled in months.

Discards (in tons). They are the main source of food for seabirds. Amount of discards is a proportion of the catch. It is generally low in the wet season and high in the dry season. Discards, influences both the birth and death rates of terns.

Terns (in numbers). They are seabirds

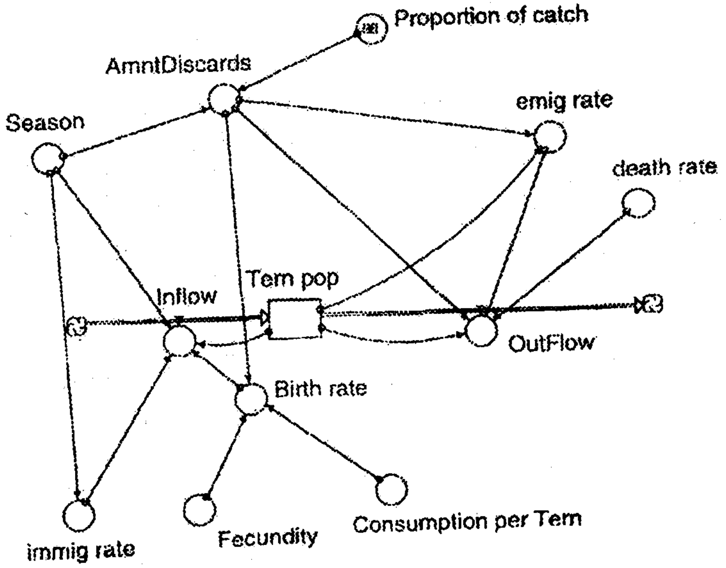

Fig. 1. Forester diagram showing inflows and outflows into tern population

adapted to marine life and belonging to the order Lariformes. The primary cause of mortality in terns is starvation. Tern population at any given time is influenced by the rate of births, deaths and migration. The population is modeled to follow the logistic growth equation. In the dry season, which coincides with winter in Europe, migratory terns join the local population in Ghana mainly because they cannot find enough food. In the event that there is not enough food for terns in Ghana, they immigrate to other suitable locations in the tropics.

Climate. There are two main climatic seasons in Ghana: dry season (November-April) and wet season (May-October). These seasons are the driving forces that determine the amount of catch and, therefore, discards as well as the immigration of terns into Ghana.

Equations and terms

$N_t = (N_{t-dt}) + (\text{Inflow} - \text{Outflow})*dt$,

where

N_t = Size of tern population at time t

Inflow = (Death rate *N) + Immigration rate *Season

Outflow = (Death rate* N) + Emigration rate * Amount of discards, where

Birth rate = Fecundity * Consumption/tern* Amount of discards

Fecundity = 3/12 = 0.25/month (Nelson, 1980)

Consumption/tern = 0.006 tons/tern

Amount of Discards (tons) =(2000*Sin (Pi*Season/6-Pi/2)+2500))*Proportion of Catch

Season = Time

Proportion of Catch = 0.75 (initial value – Nunoo, 1997)

Death rate = 1/Lifespan = 1/26/12 = 0.003/month (Nelson, 1980)

Immigration rate = (4500*Pi/6)*Sin(Pi/6*Season)

Emigration rate = Amount of Discards/ N_t

- Fecundity is taken as the mean clutch size of terms per month. •

- Consumption per tern is the amount of food eaten by a tern in a month.
- Death rate includes all forms of mortality such as death from starvation, predation and diseases.
- Emigration rate depends on the amount of discards available. When food is scarce, terns will move on to 'greener pastures'.
- Immigration rate is determined by climatic seasons. Both 'Amount of discards' and 'Immigration rate' are empirically modeled to vary sinusoidally with season.

Assumptions

- Discards are available throughout the year. Quantity of discards depends on amount of catch, which varies sinusoidally (high between April-October and low between November-March) with season in each year.
- Amount of discards taken by seabirds is equal to the amount consumed.
- Birth, death and emigration rates of sea birds depend on the amount of discards available.
- Hatching rate of term eggs is 100%
- Immigration rate of seabirds is independent of discard availability but rather determined by two climatic seasons.
- Fishermen will accept measures to reduce discards at sea in as much as quantities of target species are not drastically affected.

With all the terms and equation defined, the model was ready to be run. Four different scenarios were run and the results of each plotted on graphs. The scenarios were:

1. Changes in the size of tern population within a year at the observed discarding rate of 75% of catch;
2. Changes in tern population size over a 10 year period at the observed discard rate of 75% of catch;
3. Effect on the tern population of different proportions of catch, 0-85% discarded; and
4. Changes in tern population size at a reasonably chosen proportion of catch discarded.

Results

Results are presented in Fig. 1- 5. Fig. 2 and 3 indicate that terns, with increased food availability in the form of fishery discards, increase the size of the population over time. Within a year, size of tern population is stable between January and March, and exhibits gradual increase from April to July. The increasing trend continues till the population peaks between October and December (Fig. 2). The simulation also indicated that if this level of food availability continued over a 120-month period, the population of terns could be maintained at reasonable levels up to about 96 months but, thereafter, would escalate to intolerable limits (Fig. 3).

Fig. 4 shows that low amount of discards support smaller sizes of peak tern population while high proportions of catch discarded significantly increases the peak size of tern population. When various proportions of catch were tried, it was found out that a reduction in discards from 75% of catch to 45% of catch could maintain tern population at reasonable levels. Thus at the reduced level of 45% of catch simulated over 120 months, though the trend was similar to that shown in Fig. 3, the size of tern

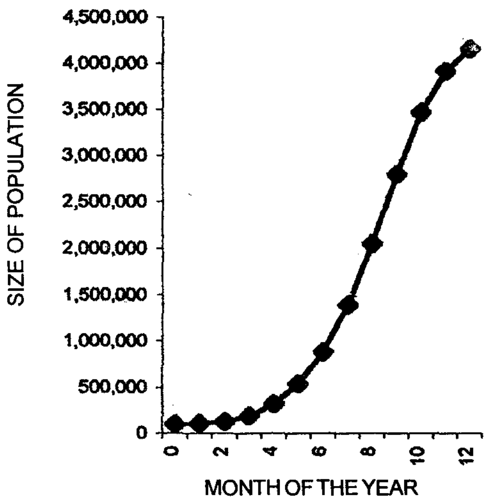

Fig. 1. Changes in the size of tern population in a year at present discard rate

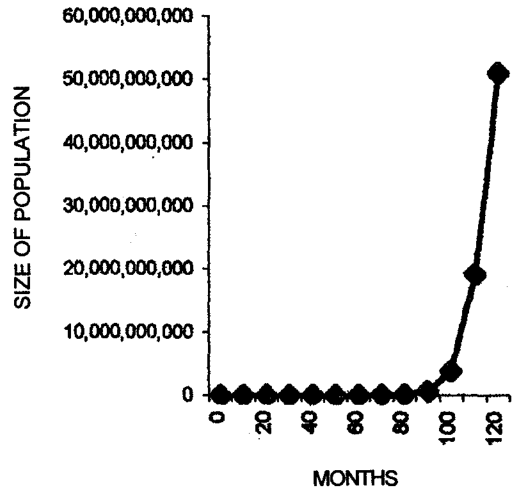

Fig. 2. Changes in the size of tern population through time at present discard rate

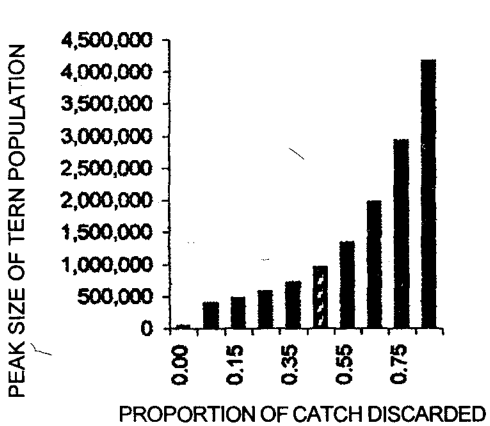

Fig. 3. Effect of changes in amount of discards on peak size of tern population

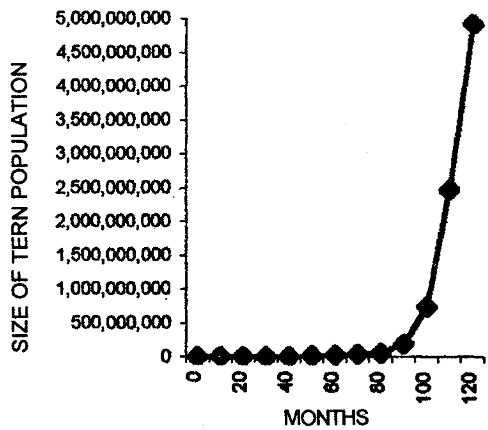

Fig. 4. Changes in the size of tern population through time at reduced discard rate

population was drastically reduced. There was a more than 10 fold decrease in tern population size (Fig. 5).

Discussion

The trend in the changes in tern population within a year mimics what have been observed on the ground in studies on waterbirds along the Ghanaian coast (Amoah *et. al.*, 2000). Avifauna from temperate regions of the world travel to the tropics during winter and return to their bases when conditions become favourable. Their numbers peak in Ghana between October to December. The birds begin to depart the shores of Ghana from January. Between February and July, the numbers are relatively low and consist mostly of residential species.

The population of terns attained after 10 years of simulation is quite huge but not impossible if discarding practice is not regulated. Foı instance, 5.9 million seabirds was estimated in the North Sea in 1995 (Garthe *et al*., 1996) due to the increasing availability of fish discards while along a relatively small stretch of the coast of Ghana, the Keta and Songor lagoons have together recorded a peak count of over 100,000 waterbirds including terns (EPC, 1990). There is, therefore, the need to set up control measures to check the commonly occurring discarding practice from the already large and growing fleet of shrimps, trawlers, inshore vessels and canoes found in West Africa.

The regulation of discarding practice needs the co-operation of all stakeholders, including researchers, tourism managers, local authorities and fishermen. The main concerns of fishermen bothers on the inherent reduction of their landings and the time lost in sorting and handling the discards. It is envisaged that the simulated reduction in discards might not reduce landings of fishermen but rather increase landed catch. Because, in Ghana, the months of October to December fall within the lean season, when the target species of shrimps are in very low amounts and thus more of the catch is discarded. Thus, the reduction of discards could be concentrated and intensified in the lean months of catch. This is based from the findings of the model that a reduction in amount of discards from 75% to 45% of catch will not adversely affect tern populations both in the short– and long-terms.

Management strategies to regulate by-catch and, therefore, discards that have been tried and tested in various places with varied successes include enforcement of 'By-catch-Reduction-Devices' on trawl net (Isaken *et. al.*, 1992), selective gear designs (Thorsteinsson, 1992; Broadhurst *et. al.*, 1999), restricted licensing of trawlers, area closure and seasonal closure (Rothlisberg , Hill & Staples, 1985; Unar & Naamin, 1984,) would help in the reduction of discards. Also, increased by-catch utilization (IDRC, 1982; Kennelly, 1995) and provision of economic incentives to alter discarding behaviour would achieve some amount of discard reduction. In addition, creating awareness through education and the dedication of vessels to collect discards from fishermen at sea are necessary.

The model can be dynamically adapted and tested with data by researchers worldwide to find solutions to the nagging problem of discarding potential food for man and its associated conflicts of interest with other natural resources. Though the model has been useful in helping to understand the dynamics of tern population, it could have been improved by the inclusion of other factors other than food. When these are adequately built into this model, the population size could be further regulated and maintained at reasonable limits for several generations to come. A sustained bird population throughout the year is possible with the interplay of both natural and anthropogenic factors. They include diseases, predation, and other density dependent factors in an environment.

Conclusion

The study has shown that a reduction in amount of discards from 75% to 45% of catch will not adversely affect tern populations both in the short- and long-terms. The reduction of discards could take place in the lean months of catch, especially in October to December in the case of Ghana.

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References

Alverson, D. L., Freeberg, M. H., Murawski, S. A. & Pope, J. G. (1994). A global assessment of fisheries by-catch and discards. *FAO Fisheries Technical Paper* No. 339, 233 pp.

Amoah, C. M., de Graft-Johnson, K. A. A., Adomako, J. K. & Nunoo, F. K. E. (2000). *Ecological Baseline Survey for Korle Lagoon.* Accra Waste Project Consultants Report. Scott Wilson Kirkpatrick Co. Ltd., Scotland.

Andrew, N. L. & Pepperell, J. G. (1992). The by-catch of shrimp trawl fisheries. *Oceanography and Marine Biology Annual Review* **30**, 527-565.

Broadhurst, M. K., Larsen, R. B., Kennelly, S. J. & McShane, P. E. (1999). Use and success of composite square-mesh cod-ends in reducing by-catch and in improving size selectively of prawns in Gulf St. Vincent, South Australia. *Fisheries Bulletin* 97, 434-448.

EPC (1990). *Coastal Zone Indicative Management Plan.* Accra, Ghana: Environmental Protection Council.

FAO (1999). *The state of the world fisheries and aquaculture 1998.* Rome: FAO. 112 pp.

Furness, R. W. (1982). Competition between fisheries and seabird communities. *Advances in Marine Biology* **20**, 225-309.

Garthe, S., Camphuysen, C. J. & Furness, R. W. (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. *Advances in Marine Biology* **20**, 225-309.

Gaston, G. R. (1990). Shrimp and by-catch: the problem is in the trawl. *Water Log* **10**, 3-5.

Haefner, J. W. (1996) *Modeling biological systems. Principles and applications.* Chapman and Hall. 473 pp.

IDRC (1982). Fish by-catch – Bonus from the sea. *Report of a technical consultation on shrimp by-catch utilization held in Georgetown, Guyana, 27-30 Oct. 1981.* Ottawa: IDRC. (IDRC – 198e).

Isaken, B., Valdemarsen, J. W., Larsen, R. B & Karlsen, L. (1992). Reduction of fish by-catch in shrimp trawl using a rigid separator grid in the aft belly. *Fisheries Research* **13**, 335-352.

Kennelly, S. J. (1995). The issue of by-catch in Australian demersal trawl fisheries. *Reviews in Fish Biology and Fisheries* **5**, *213-234.*

Nelson, B. (1980). *Seabirds – their biology and ecology.* London: Hamlyn. 224 pp.

Nunoo, F. K. E. (1998). 'By-catch': A problem of the industrial shrimp fishery in Ghana. *Journal of the Ghana Science Association* **1**, 17-23.

Nunoo, F. K. E. (1997). *The by-catch problem of the industrial shrimp fishery in Ghana.* (M.Phil. Thesis). University of Newcastle, U.K. 129 pp.

Rothlisberg, P. C., Hill, B. J. & Staples, D. J. (1985). *Second National Prawn Seminar. Cleveland, Australia.* 139 pp.

Saila, S. B. (1983) Importance and assessment of discards in commercial fisheries. *FAO Fishery Circular* 765. 62 pp.

Thorsteinsson, G. (1992). The use of square mesh cod-ends in the Icelandic shrimp, *Pandalus borealis, fishery. Fisheries Research* **13**, 255-266.

Tillman, M. F. (1993) By-catch – the issue of the 90's. In *International Conference on Shrimp By-catch, May, 1992, Lake Buena Vista, Florida* (R. P. Jones, ed.), pp. 13-18. Tallahassee: Southeastern Fisheries Association.

Unar, M. & Naamin, N. (1984). A review of Indonesian shrimp fisheries and their management. In *Penaeid Shrimps – their Biology and Management*, (J.A. Gulland and B.J. Rothschild, ed.), pp. 104-110. Surrey, UK: Fishing News Books Ltd.