

# Proposal for a SCOR Working Group to Investigate Mesopelagic Fish Populations As Potential Fishery Stocks

## Summary

As the world's ocean fisheries have exploited more and more of the world's fishery stocks, there has been greater emphasis on finding new fish stocks. Among possible new stocks, the most abundant and widespread are the mesopelagic fishes of the world ocean. These are the small fishes that are widespread and common, usually found at depths from 100 to 1000 meters below the surface. Among the most abundant and considered typical of that fauna are the lanternfishes or myctophids of the family Myctophidae.

Suggestions and initial attempts have been made to begin fishing for lanternfish populations. Some of these are incredibly numerous in certain locations and at certain times, for example: the lanternfish *Benthoosema pterotum* in the Gulf of Oman and adjacent parts of the Arabian Sea. However, any kind of sustained fishery is dependent on regulating the fishery, based on an understanding of the biology and population dynamics of the exploited species and their predators. For virtually all species of mesopelagic fish, that knowledge is sorely lacking or non-existent.

The proposed working group will focus on lanternfish as the most likely to be exploited in the future. Conducted over a period of four years, the working group will culminate in a final report that will (1) summarize past results on the state of understanding of myctophid biology and population dynamics; (2) assess ongoing efforts in these and related fields; and (3) assess what types of research efforts need to be carried out to increase understanding of myctophids as commercially exploited species. With the advent of new and powerful molecular tools in recent decades, the focus on biomolecular approaches give promise of new and faster ways of determining the population dynamics of mesopelagic species before any serious exploitation even starts. The idea of using these and other advanced techniques will be central to the considerations and discussions of the proposed Working Group. The working group will also establish and maintain a Web site for the exchange of information between mesopelagic ichthyologists and fishery scientists. Such a Web site should help with planning for future research through the exchange of ideas and approaches.

## Rationale

The commercial fisheries of the world ocean have become more and more efficient and capable in their exploitation of existing fish stocks. World population growth and economic development have put increasing pressure on finding and developing new fishery resources. As the possible exploitation of these potential new fishery stocks becomes more economically viable, there is no question that such development will take place, it is only a matter of when, where, and how. It is also clear that such exploitation must be done in a rational and sustainable fashion. However, sustainability is dependent upon knowledge of the population dynamics and biology of the

exploitable species. Development of such a knowledge database depends on basic research into the population dynamics and biology of the exploitable species.

Among the largest such potential commercial fishery stocks are the vast numbers of mesopelagic fish that are found in the midlayers of the world ocean, typically from 100 to 1000 meters below the surface. While there are many species from many families that constitute that fauna, the lanternfishes or myctophids of the family Myctophidae are perhaps the most widespread and ubiquitous. They have also been found to occur in enormous numbers and great abundance in particular times and places. A prime example of this is the lanternfish *Benthosema pterotum* found in the Gulf of Oman and adjacent areas of the Arabian Sea.

The proposed SCOR Working Group would focus international attention on myctophid fish species. It is the most logical way to explore the dual problem of the lack of knowledge of the population dynamics and biology of these lanternfish together with a lack of understanding of what impact the wholesale removal of these fish might potentially mean to ocean ecosystems, particularly on the predators that prey on the myctophids. While the kind of research that must be conducted is basic research, it is clearly of practical importance to future fisheries development. Furthermore, because the potentially exploitable fish populations are global in distribution, the basic research needed has global implications. It is timely to constitute such a working group at this time because large-scale exploitation of these fish has not yet expanded worldwide, but an exploratory commercial fishery effort for myctophids is being carried out by Iran in their part of the Gulf of Oman. The countries of Oman and Pakistan are also interested in investigating a potential mesopelagic fishery and other Indian Ocean countries may soon follow.

### **Scientific Background**

The pelagic realm of the world's open ocean is the most extensive environment on the planet, arguably covering up to half of the Earth's surface. The surface portions of this realm, referred to as the epipelagic, have long supported important fisheries including tunas, swordfish, mahi mahi and various open ocean sharks. As the world's fisheries have become more extensive and intensive, pressure has grown to exploit new fish species. One area of potential investigation is in the pelagic, not the near surface, but the mesopelagic, the realm from approximately 100 to 1000 meters below the surface. This realm is inhabited by large populations of small fish, abundant and widely distributed. Among the most common and abundant are the lanternfishes of the family Myctophidae, the myctophids.

It has long been recognized that at some times and places myctophids can become extremely common and abundant. A prime example of this kind of extreme abundance is in the midwaters of the northwest Arabian Sea and adjacent Gulf of Oman where in the mid-1970s through 1983, Norwegian fishery scientists led by Dr. Jakob Gjosaeter of the University of Bergen conducted fisheries surveys. Those surveys were conducted aboard the fishery research vessel R/V *Dr. Fridtjof Nansen* belonging to the Norwegian Agency for International Development (NORAD) under the joint auspices of the UN Food and Agriculture Organization (FAO) and NORAD. He and his colleagues reported that there was a large standing stock of these mesopelagic fishes, principally a few species of myctophids (Gjosaeter and Kawaguchi, 1980; Gjosaeter, 1981; Aglen et al., 1982; Gjosaeter, 1984). Using net sampling and based on acoustic returns using the

ship's echosounders, they estimated a standing stock of some 100 million metric tons (Gjosaeter and Kawaguchi, 1980, Fig. 12.4, Table 12.4) for the entire region. Considering that the entire world's commercial fisheries catch is somewhere between 40 and 100 million tons annually, it means that if this estimate is accurate, it has the potential to be a very large fishery.

In the Gulf of Oman, the only myctophid present is *Benthosema pterotum* and the Iranians have started a commercial fishery for myctophids in their part of the Gulf of Oman (pers. comm. Shahid Amjad, 2003). In the adjacent areas of the Arabian Sea outside the mouth of the Gulf, the main species reported in abundance is *B. pterotum* (Gjosaeter, 1981, Fig. 1, Table 1) and to a lesser extent further offshore, its close relative *B. fibulatum* (Nafpaktitis and Nafpaktitis, 1969, Fig. 11). Perhaps because of the abundance and potential commercial importance of *B. pterotum*, a surprisingly large amount of research has been conducted on this species and somewhat less on *B. fibulatum*. Scientists from a number of countries have contributed to this database. In Pakistan, Hussain and Ali-Khan (1987) studied the fecundity of both species. They found that *B. pterotum* females showed a fecundity of 200 - 1300 eggs while the larger *B. fibulatum* showed a fecundity of 400 - 5000 eggs. From Norway, Dalpadado (1988) studied the reproductive biology of *B. pterotum* and found indications that it spawns only once, but could not draw firm conclusions; Gjosaeter and Tilseth (1988) studied its spawning and larval development in the Gulf of Oman, finding that it spawns at night at depths from 100 - 300 meters below the surface and the slightly positively buoyant eggs drift upward and hatch in 10 hours in the 25 degree (C) water; and Dalpadado and Gjosaeter (1988) reported that most, if not all of the feeding took place at night in the epipelagic realm and was on zooplankton, primarily copepods. In Russia, Tsokur (1981, Fig. 2) illustrated the larvae of *B. pterotum* (as *Benthosema pterota*) from the Arabian Sea. In India, K. Gopakumar et al. (1983) reported on the fatty acid composition liberated from the lipids of lanternfish (ibid., Table 4) and Lekshminair et al (1983) did a nutritional evaluation of the fish meal and fish hydrolysates from Gulf of Oman myctophids and found them to be of good quality, which could be used as a protein supplement in animal feeds. In Oman on 7 - 9 May 2001, a Workshop on Mesopelagic Fishes was held in Muscat under the auspices of FAO and an Information Paper, excerpted from Chapter 3.4 of Saetersdal et al. (1999) reviewed the R/V *Dr. Fridtjof Nansen* work in the Arabian Sea and reevaluated the estimated standing stock quantities of myctophids. The estimate for the entire region was reduced to some 47 million metric tons. Though this is about half of the original estimate of 100 million tons, it is still a huge standing stock.

The above discussion illustrates that while there is probably more known about the biology of *B. pterotum* and its congener, *B. fibulatum*, than any other myctophid species or species pair, little is known about the population dynamics (crucial information if a fishery for this species is to be a sustainable one), or of their role in the ecosystem as predator and as prey. Much less is known about virtually all of the remaining described species of myctophids in the world (probably more than 300) and this must be the focus of the Working Group's efforts.

## **Statement of Work/Terms of Reference**

It will be the goal of this Working Group to:

- 1) Summarize the state of knowledge of methods and techniques for determining the population dynamics of mesopelagic fish and the state of knowledge about myctophid biology, especially as it pertains to an understanding of the population dynamics of myctophid species and their role in marine ecosystems, including effects that removing the myctophids would have on the predator species that prey on them.
- 2) Assess ongoing research efforts on the above topics, especially including and emphasizing the utilization of modern molecular techniques and approaches.
- 3) Target which myctophid species and which geographic areas in the world ocean could most profitably benefit from a focus of these and other innovative research approaches.
- 4) Establish and maintain a Web site for the exchange of information and ideas between mesopelagic fish specialists and fishery specialists.
- 5) Produce a comprehensive report incorporating the results from the above activities for which we would seek publication as a peer-reviewed journal paper or special issue, or a book.

## **Meetings**

It is proposed that the Working Group have a duration of 4 years with three meetings of the members over that period. The first working group meeting would take place within three to six months after the availability of funds. The primary task of the first meeting will be the resolution of what procedures to use in order to come up with the best possible final report, including time lines and which working group members will be responsible to bring together the information for past and ongoing efforts on different topics, most logically by geographic areas. The secondary task of the first meeting will be determining the steps for the establishment of a Web site for the exchange of information among myctophid and fishery specialists. It is clear that a working group of ten members plus an indeterminate number of associate members will have difficulty bringing in all the necessary knowledge of ongoing efforts, let alone potential future efforts. Therefore, one of the activities at the first working group meeting will be the planning for an international conference of myctophid specialists and related marine scientists including fishery biologists. It is anticipated that this conference will build on the results of the 2001 FAO mesopelagic fish conference in Muscat but will differ in focusing: 1) heavily on myctophids and 2) on a world-wide basis rather than only emphasizing the Arabian Sea region. It is expected that such a conference would occur 18 - 24 months after the first working group meeting and would bring together some 40 - 50 specialists from all parts of the world. Support for such a conference would be sought from other agencies, private foundations and other sources. If such a conference were not held, it would not negate the importance of the Working Group's final report. However, incorporating the results of a successful international myctophid conference would enhance the Working Group's final report by making it more comprehensive and inclusive.

The second working group meeting would be held after the international conference, ideally, immediately afterwards. On the agenda would be a discussion of how to incorporate the results from the conference into the final report, that is, what actions and activities would need to be carried out by the group members in order to have the results ready for incorporation into the final report. This would result in an initial draft that would be circulated electronically to the members who would be free to solicit comments and inputs from other specialists. These inputs from the members would be brought together electronically into a revised draft which would be discussed and finalized at the third and last working group meeting, to be held approximately 12 months after the second meeting.

This timetable is reasonable and allows for some slippage of dates and times which will still permit completion of the working group activities as well as the final report within the planned 4-year period.

Time 0 -- Availability of funds  
3 - 6 months later -- W.G. Meeting One  
18 - 24 months later -- International Myctophid Conference  
1 day - 1 month later -- W.G. Meeting Two  
12 months later -- W.G. Meeting Three  
3 months later -- Final report ready for publication

### **Working Group Membership**

The Working Group membership will consist of 10 members from a variety of countries including both developed and developing countries. It will include both myctophid specialists and fishery specialists already involved in, or with an interest in, possible myctophid fisheries. Because of the interest and potential importance of the known large populations of myctophids in the northwestern Arabian Sea, several members are from countries bordering that area, including one of the two co-chairs. Involvement of these individuals could be beneficial to SCOR by involving scientists from countries that have not been substantially involved in SCOR activities in the past (i.e., Pakistan, Iran, Oman, and Ukraine).

### Full Members

Bernard Zahuranec, Co-Chair, USA -- An active and recognized researcher on the systematics and biogeography of myctophids. Career as a program officer at the US Office of Naval Research provided experience in setting up and running international conferences.

M.M. Rabbani, Co-Chair, Pakistan -- Director General of NIO (National Institute of Oceanography) in Karachi. As D.G., he is the *ex officio* marine scientist who will be the Pakistani collaborator for a US - Pakistan research project on Arabian Sea myctophid genomics proposed between University of California, Santa Cruz (UCSC) and NIO Karachi.

Myctophid Fishery representative, Iran -- Past personal communications indicated that Iran has started an exploratory fishery for mesopelagic fish (*Benthosema pterotum*) in their part of the Gulf of Oman so this position is for a knowledgeable member of that fishery organization but specific information about who that would be has been difficult to obtain. It is possible that the

best place to start would be with Mr. Lotfollah Saeedi as Deputy Minister and first President of Iran Fisheries Organization.

Younis Al Akhzami, Oman -- As Director of the Fisheries Division of the Ministry of Agriculture and Fisheries, he is in the best position to represent Oman's interest in potential mesopelagic fisheries and their future plans for such fisheries.

Gopakumar Kumara, India -- As an active researcher early in his career, he and his colleagues published the most extensive and complete studies on the biochemistry and food value of *Benthoosema pterotum*, the extremely abundant mesopelagic myctophid in the Gulf of Oman and adjacent waters of the Arabian Sea. His final government position before retirement as Director of the Fisheries Division in the Ministry of Agriculture gives him a unique perspective and knowledge on the status of the marine fisheries of India.

Hiroya Sugisaki, Japan -- This young researcher (suggested by Dr. Akira Taniguchi) has, with colleagues listed below as possible Associate Members, been actively involved in conducting research into the potential for mesopelagic fisheries resources in the seas around Japan.

P. Alexander Hulley, South Africa -- Presently Assistant Director of the South African Museum in Capetown, his administrative duties have not prevented him from continuing an active research program on the systematics and biogeography of myctophids. His efforts have particularly focused on the myctophids of the Atlantic and Indian Oceans.

John Paxton, Australia -- Presently retired from the Australian Museum in Sydney, he has nevertheless continued active research in ichthyology. His publications deal with the relationships of various species of myctophids and his past publication on the relationship of the many myctophid genera is a classic standard for the field.

Cynthia Klepadlo, USA -- As an assistant curator in the Fish Collection of the Scripps Institution of Oceanography, she has had extensive experience with mesopelagic fish, especially with Pacific species. This personal interest has prompted her to develop a comprehensive bibliography of myctophid publications, presently well in excess of a thousand entries, which she has offered to share with the other Working Group members.

Alexander Boltachev, Ukraine -- As an active marine ichthyologist, together with his colleague, Sergey Tsarin, in the Institute for Studies of the Biology of Southern Seas in Sevastopol, they have access to a huge collection of mesopelagic fish from all tropical seas, but with special emphasis in the Indian Ocean and southwest Pacific Ocean. This has given them unique insights and understanding of the systematics, biology and ecology of these fish.

#### Associate Members

Giacomo Bernardi, USA -- As an ichthyologist who employs molecular techniques, he is the Principal Investigator in the US - Pakistan cooperative project proposed to study the genomics of myctophids in the northwest Arabian Sea and adjacent Gulf of Oman discussed under Dr. M. M. Ribbani, above.

T.M.A. Khan, Pakistan -- Proposed by Dr. M. M. Rabbani, this young and energetic biological oceanographer has been included as a potential stand-in for Dr. Rabbani, should his duties as Director General of NIO Karachi prevent his participation in a Working Group meeting.

Masatoshi Moku, Japan -- A colleague of Dr. H. Sugisaki (listed above) included here for the same reasons as Dr. Sugisaki.

Chiyuki Sassa, Japan -- A colleague of Drs. Sugisaki and Moku, he has also provided material of several forms of *Benthoosema* to Dr. Bernardi for comparative molecular genomic analyses.

Sergey Tsarin, Ukraine -- See discussion under Alexander Boltachev, above.

Padmini Dalpadado, Norway -- An active researcher at the Fisheries Institute of the University of Bergen whose PhD dissertation spelled out most of what is known about *Benthoosema pterotum* in the Gulf of Oman, making it, arguably, the best understood myctophid in the world.

Frans Teutscher, FAO Rome -- As a participant in the 2001 Workshop on Mesopelagic Fishes supported by FAO in Muscat, Oman, he presented a paper entitled: "Options for utilization of lanternfish (*Benthoosema pterotum*, Myctophidae) in the Gulf of Oman".

Wilfried Thiele, FAO Rome -- As another participant in the 2001 Muscat workshop, he co-authored a paper entitled: "Efficient capture and handling of lantern fish". The potential participation of Drs. Thiele and/or Teutscher (or perhaps other FAO scientists) would strengthen the output of the Working Group.

Eugene Fritz, USA -- Retired from National Marine Fisheries Service headquarters in Washington, DC, his knowledge of the fisheries of the world is encyclopedic and his approach to some of the problems has often been innovative and unorthodox, an approach that might prove especially welcome in dealing with the problems posed by potential mesopelagic fisheries.

## References

- Aglen, A., Gjosaeter, J., Myrseth, B., and Tilseth, S., (1982) Surveys of mesopelagic fish resources in the Gulf of Oman and the Gulf of Aden Jul - Aug 1979 and Jan - Feb 1981. *Report of Surveys with the R/V Dr. Fridtof Nansen*, Institute of Marine Research, Bergen, Norway, 71 pages.
- Amjad, S. (2003) Personal communication to B. Zahuranec.
- Dalpadado, P. (1988) Reproductive biology of the lanternfish *Benthoosema pterotum* from the Indian Ocean. *Mar. Biol.* 98:307-316.
- Dalpadado, P. and Gjosaeter, J. (1988) Feeding ecology of the lanternfish *Benthoosema pterotum* from the Indian Ocean. *Mar. Biol.* 99:555-567.
- Gjosaeter, J., (1981) Abundance and production of lanternfish (Myctophidae) in the western and northern Arabian Sea. *Fiskeridirektoratets Skrifter Serie Havundersokelser* 17(6): 215-251.
- \_\_\_\_\_. (1984) Mesopelagic fish, a large potential resource in the Arabian Sea. *Deep-Sea Res., Part A*, 31(6-8): 1019-1035.

- Gjosaeter, J. and Kawaguchi, K. (1980) A review of the world resources of mesopelagic fish. *FAO Tech. Rept.* (193):1-157.
- Gjosaeter, J. and Tilseth, S. (1988) Spawning behaviour, egg and larval development of the myctophid fish *Benthoosema pterotum*. *Mar. Biol.* 98(1):1-6.
- Gopakumar, K., Ramachandran Nair, K.G., Viswanathan Nair, P.G., Lekshmy Nair, A., Radhakrishnan, A.G., and Ravindranathan Nair, P. (1983) Studies on lantern fish (*Benthoosema pterotum*). 1. Biochemical and microbiological investigations. *Fishery Technology* 20(1): 17-19.
- Hussain, S.M., and Ali-Khan, J. (1987) Fecundity of *Benthoosema fibulatum* and *Benthoosema pterotum* from the northern Arabian Sea. *Deep-Sea Res., Part A*, 34(7):1293-1299.
- Lekshminair, A., Arul James, M., Mathew, P.T., and Gopakumar, K. (1983) Studies on lantern fish (*Benthoosema pterotum*) 2. Nutritional evaluation. *Fishery Technology* 20(1): 20-23.
- Nafpaktitis, B.G., and Nafpaktitis, M. (1969) Lanternfishes (family Myctophidae) collected during cruises 3 and 6 of the R/V 'Anton Brunn' in the Indian Ocean. *Bull. LACM Nat. Hist., Sci.* 5:1-79.
- Saetersdal, G., Bianchi, G., Stromme, T. and Venema, S. C. (1999) The DR. FRIDTJOF NANSEN Programme 1975 - 1993. Investigations of fishery resources in developing countries. History of the programme and review of results. *FAO Fisheries Technical paper No. 391*, FAO, Rome, Italy, 452 pages. [Original not seen]
- Tsokur, A.G. (1981) Larvae of *Benthoosema pterota* (Alcock 1891) (Myctophidae) from the Arabian Sea. *Vopr. Ikhtiol.* 21(3): 450-466. [(1982) *J. Ichthyol.* 21(3):38-53]