SHORT COMMUNICATION

SARSIA

MASS OCCURRENCE OF THE PHYSONECT SIPHONOPHORE *APOLEMIA UVARIA* (LESUEUR) IN NORWEGIAN WATERS

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SYNOPSIS

At the end of November 1997 salmon farmers in Hordaland County on the coast of western Norway reported mass occurrence of an unknown animal that caused severe lesions and death of fishes. The organism was identified as the physonect siphonophore *Apolemia uvaria*. A survey of reported sightings (Fig. 1) shows that the species ranged from Gullmarsfjorden on the Swedish west coast to Finnmark in northern Norway. The first known observation from Scandinavia was from Kosterfjorden in western Sweden in early November. After news about death of farmed salmon was first made public by radio, television and newspapers in the last part of November, additional reports arrived almost concomitantly from sites all along the coast (see reports in Havbruksrevyen, internet: http://www.intrafish.no). Based on problems reported by salmon farmers it seemed that the abundance of siphonophores along the mid-Norway coast decreased after mid December (Karl Tangen, pers. commn). In mid December we made a field survey from Svinøy along a 300 km transect to the northwest (see Fig. 1), where CTD casts and zooplankton sampling (1-m^2 MOCNESS and a WP2 net) were performed. These collections showed that *A. uvaria* was present in coastal water as well as in open ocean water and that it occurred as deep as 300 m, mainly in Atlantic water, indicating an origin from the Atlantic (Fig. 2). Only one of four samples from the transect parallel to the coastline south of Svinøy contained *A. uvaria*. Between mid December and the beginning of February 1998 *Apolemia* also occurred within the inner parts of fjords in Rogaland County and southern Hordaland County, and was also present in open waters, although no further problems for salmon farmers were reported after December 1997.

BIOLOGY AND DISTRIBUTION OF THE SPECIES

Apolemia uvaria is described from the Mediterranean Sea, and has been reported from the Strait of Messina and near Villefrance-sur-Mer on the southwestern French coast (see references in Totton 1965). It occurs there in areas characterised by frequent upwelling of deep water and is therefore defined as a midwater species. *Apolemia uvaria* has been reported off Fuerteventura in the Canary Islands (Pugh 1974), and off northern Namibia in Africa (Pagés & Gili 1991). Leloup (1955) considered the species to be common in both the Atlantic and Indian Oceans, as well as in the Mediterranean, and to have a wide depth distribution. The species has also been found in Monterey Bay, California with remotely operated vehicles, ROV (Marsh Youngbluth & Bruce Robison, pers. commns) and off Santa Barbara in California (Alldredge & al. 1984). In these regions *Apolemia* appears principally in hypoxic waters from 450 to 800 m. Unpublished observations by Biggs, Youngbluth and Alvariño from the Sargasso Sea, Bahamas and Antarctic waters, respectively, (Marsh Youngbluth, pers. commn) strengthen the impression of a global distribution of this species. The

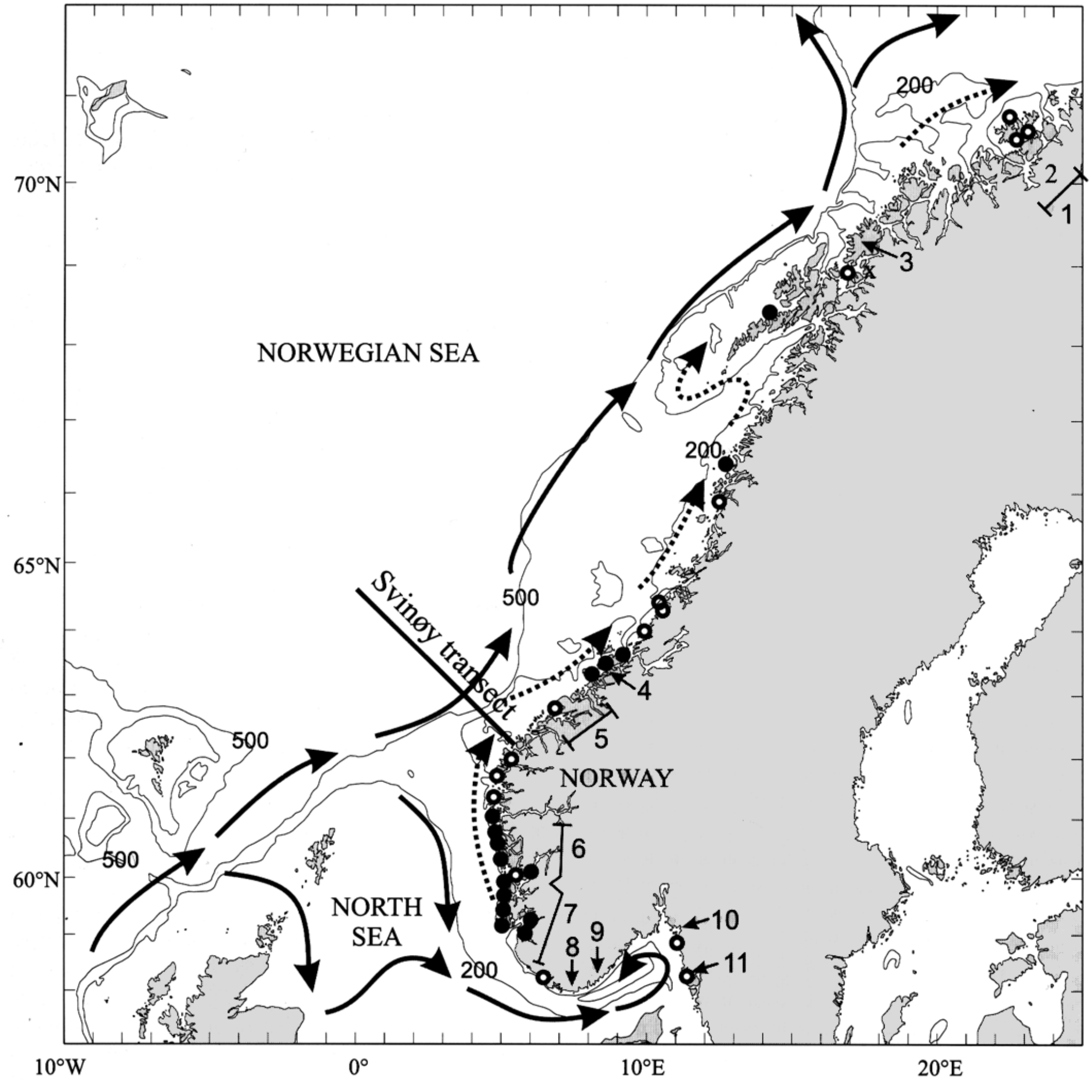

Fig. 1. Map of the area and reported occurrence of *Apolemia uvaria* (data from Oceanor AS provided by Karl Tangen). Location of the Svinøy transects with hydrography and zooplankton stations is marked. Filled circles: mass occurrence of *Apolemia* and reported problems for salmon farmers. Open circles: low abundance of *Apolemia* and no reported problems from salmon farmers. The main current system with the North Atlantic Current and the Norwegian Coastal Current (broken line) is displayed. Coastline locations: 1. Finnmark County, 2. Altafjorden, 3. Senja, 4. Hitra, 5. Møre og Romsdal County, 6. Hordaland County, 7. Rogaland County, 8. Søgne, 9. Arendal, 10. Kosterfjorden, 11. Gullmarsfjorden.

observations by Fraser (1961, 1967) showed that the species was not only present in the oceanic warm water but also in the cold waters of the North Sea. According to Kirkpatrick & Pugh (1984) it has been recorded from the North Sea, as far north as Scotland, where it occurs mainly in the upper 100 m. Hitherto it has not been reported from Scandinavian waters (but see later about reports from fishermen). Previous to the present observations *A. uvaria* was not observed in shallow water or in areas of reduced salinity (Kirkpatrick & Pugh 1984).

The taxonomy is not well investigated, and the family Apolemiidae, consisting of *A. uvaria* and two relatively newly described species, *Ramosia vitiazi*

STEPANJANTS, 1967 and *Tottonia contorta* MARGULIS, 1976, is in need of revision (MACKIE & al. 1987). For example, *A. uvaria* is the only described species of the genus *Apolemia* but there is at least one more (undescribed) species (Philip Pugh, pers. commn).

Analyses of stomach contents from two colonies (including 198 gastrozooids) collected at 0-20 m depth off Santa Barbara in California show that *A. uvaria* consumes a variety of zooplankton, with shrimps and gelatinous zooplankton as dominant prey (PURCELL 1981). In Monterey Bay analysis of video records and dissections of gastrozooids from deep water populations (400-800 m) indicate that *Apolemia* colonies are opportunistic predators that feed on medusae, tomopterids, siphonophores, ctenophores, chaetognaths, salps, appendicularians, copepods, euphausiids, amphipods, sergestids and small fishes (Marsh Youngbluth, pers. commn).

According to Norwegian fishermen, the high abundance of siphonophores is not a new phenomenon. Several fishermen reported that they have frequently collected 'pearl-chain jellyfishes' in their nets. But to our knowledge this is the first time siphonophores have caused problems for salmon farmers in Norwegian waters. The only known previous event elsewhere is an 'invasion' of *Apolemia uvaria* on the west coast of Shetland in early January 1997, causing nuisance for fish farmers (Steve Hay, pers. commn). No scientists have confirmed the identification of the Norwegian fishermen's 'pearl-chains' and the identification by the fishermen from historic observations therefore leaves some doubt about this being *Apolemia uvaria*. A confusion with salps may have occurred, because these zooplankton appear as chains of gelatinous bodies of up to 1-2 m length. BRATTSTRÖM (1972) reported on the occurrence of *Salpa fusiformis* CUVIER in Norwegian coastal waters between 1955 and 1970. During a mass invasion in 1955 all fishing activities had to be stopped in the invaded areas because trawls and nets became completely filled with salps.

Apolemia uvaria from the Mediterranean Sea reaches a length of 30 m (Claude Carré, pers. commn, cited in MACKIE & al. 1987) and observations in Monterey Bay, California, have given up to 20 m length of this species, although the majority of colonies range from 2 to 8 m (Marsh Youngbluth, George Matsumoto & Bruce Robison, pers. commns). The recent observations from Scandinavian coastal waters indicated a dominance of short colonies (20-50 cm length, maximum 1-2 m) but the majority of the colonies were incomplete, i.e. without the pneumatophore and the nectosome. The absence of these structures makes a proper identification difficult, because the occurrence of unbranched tentacles

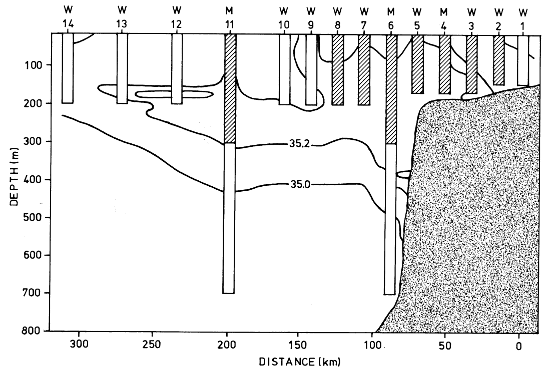

Fig. 2. Occurrence of *Apolemia uvaria* at the 14 stations along the Svinøy transect, based on WP2 samples (W, 200-0 m or bottom-0 m) and MOCNESS (M, eight sample intervals between 700 and 0 m). Shaded bars: *Apolemia* present; Open bars: *Apolemia* not present. The isohaline of 35.0 psu defines high salinity water of Atlantic origin.

at the base of each nectophore is a unique taxonomic characteristic of *Apolemia* (TOTTON 1965). This species is known to be especially prone to fragmentation (MACKIE & al. 1987). Thus it is likely that the short segments represent fragments of larger colonies that have been torn apart by mechanical disturbance of sea surface turbulence.

The colonies recovered from localities in Hordaland lacked the nectosome (Fig. 3). When caught, the stem of the colony contracts, and appears as an unbroken strand of cormidial groups. Each cormidial group hosts gastrozooids (feeding individuals), palpons (hunting, defence and digestion duties), tentacles and bracts (buoyancy individuals). This appearance is also typical for preserved material. Under natural conditions the living colony relaxes the tentacles, which in our observed material could reach a length of at least 30 cm.

EFFECTS ON FARMED SALMON

When contact is made with the net of salmon cages the colonies might easily be broken into smaller pieces, each piece with the ability to sting. The sting of this species is quite strong and the cnidocyst can penetrate the skin in the palm of a person's hand. Salmon can get open skin lesions, and this condition provides an opening for secondary infections. Stings on the eyes may destroy the sight of the fishes and stings on the gills may cause respiratory problems. Reports from the fish farmers indicate that the last type of effect is the one causing direct death of the fish. In addition to the direct interactions, the stress upon fishes experiencing stings may cause them to panic and swim into the net of the cage, thereby increasing the amount of mechanical damage to skin and muscle tissue. Reports from salmon farmers also indicate effects varying from reduced appetite and erratic behaviour to death. Salmon farmers also reported that healthy fishes actively tried to keep away from the siphonophores and high mortality was mainly related to blinded fishes (Karl Tangen, pers. commn). Fishermen have also reported problems with fyke net catches at the island Sotra, west of Bergen. The siphonophores were entangled in the fyke net and fishes inside it were killed. Any transformed effects from stung salmon to humans are not expected and there is no reason to believe that humans ingesting such meat will experience any health problems (Philip Pugh, pers. commn). The unsightly appearance of epidermal lesions caused by the stings will certainly reduce the sale value of the fish.

WHAT CAUSED THE INVASION OF *APOLEMIA UVARIA*?

Apolemia uvaria has most likely been transported to Skagerrak and the Norwegian coast by the North Atlantic Current flowing northeast off northern Scotland (see Fig. 1). The chronological order of the reports from salmon farmers is not a reliable proof of this transport process, since most of the observations were initiated by the spread of the news about the problem. The striking fact is the high abundance of siphonophores reported from the Skagerrak coast and all the way north to Finnmark, and this agrees with the main current system in the area (Fig. 1). The water from the North Atlantic Current branches off north of Scotland, transporting Atlantic water into Skagerrak along the western side of the Norwegian Trench, and mixes with the local water. This mixed water forms the Norwegian Coastal Current going northwards. The main part of the North Atlantic Current continues northward and follows the Norwegian coast parallel to the Norwegian Coastal Current, sometimes diving beneath it, and the two water masses are continuously mixed in the border area. Organisms transported by the North Atlantic Current may thus occur almost simultaneously in Skagerrak and along the Norwegian coastline. Hydrographical data from Tjärnö Marine Biological Laboratory, situated in a sheltered bight on the land side of Kosterfjorden at the Swedish Skagerrak coast, showed a dramatic change in salinity in September, increasing from 21 psu in the beginning to 29 psu in the end of the month. The salinity thereafter stayed high ($\leq$ 29 PSU) throughout November with a peak value of 34.5 psu on 28 October, normal salinity for this period being < 25 psu (Bertil Rex, pers. commn). Together with similar hydrographical observations from the Research Station at Flødevigen, Arendal, in southern Norway (Karl Tangen, pers. commn) this is suggestive of a strong influence of Atlantic water.

During October and early November unusual occurrence of more southerly species were recorded in Kosterfjorden, with high abundances of the cladoceran *Penilia avirostris* Dana, the siphonophore *Muggiaea atlantica* Cunningham and the salp *Doliolum nationalis* Borgert (Hans G. Hansson, pers. commn). These species disappeared before *Apolemia uvaria* occurred, around 10 November. This group of species has been recorded as new for the German Bight, based on a recently published 20-year investigation and its presence is coincident with higher salinity and a higher winter temperature (Greve & al. 1996). One (but not the only) possible factor causing such a change is an increased inflow of Atlantic water into the North Sea. In the southern and southwestern parts of Norway long periods with low pressures and northerly winds in October-November caused increased temperature in the surface water, thus indicating some upwelling (Karl Tangen pers. commn). Zooplankton samples from the Svinøy transect included a few specimens of typical oceanic copepods like *Aetideus armatus* (Boeck), *Pleuromamma robusta* (Dahl), and *Phaenna spinifera* Claus. To our knowledge this is the first record in Norwegian waters of *P. spinifera*, a species which has a world-wide distribution in warm waters (Rose 1933). There was a significant presence of the *Arachnactis* larva of *Cerianthus,* and the adults of this genus occur in especially high abundance north of Shetland (Hardy 1956). Thus all these observations indicate a strong influence from the North Atlantic Current.

A parallel scenario has been described for *Salpa fusiformis* in 1905 (Apstein 1911, cited in Brattström 1972) and 1955 (Brattström 1972). This is a cosmopolitan warm-water species, but also considered an indicator species of the North Atlantic Current (Fraser 1962). In both years *S. fusiformis* occurred with highest abundance between the counties Hordaland and Møre og Romsdal, in 1905 also reported from Skagerrak. There is therefore no doubt about the geographical origin of *Apolemia uvaria* during the present invasion.

THE FUTURE FOR *APOLEMIA UVARIA* IN NORWEGIAN WATERS

Based on the geographical distribution of *A. uvaria* reported above it is highly probable that this siphonophore may survive in the hydrographical regime existing in our fjords and shelf areas. Without any further advection from the North Atlantic Current any prolonged occurrence will probably be restricted to the fjords. This was

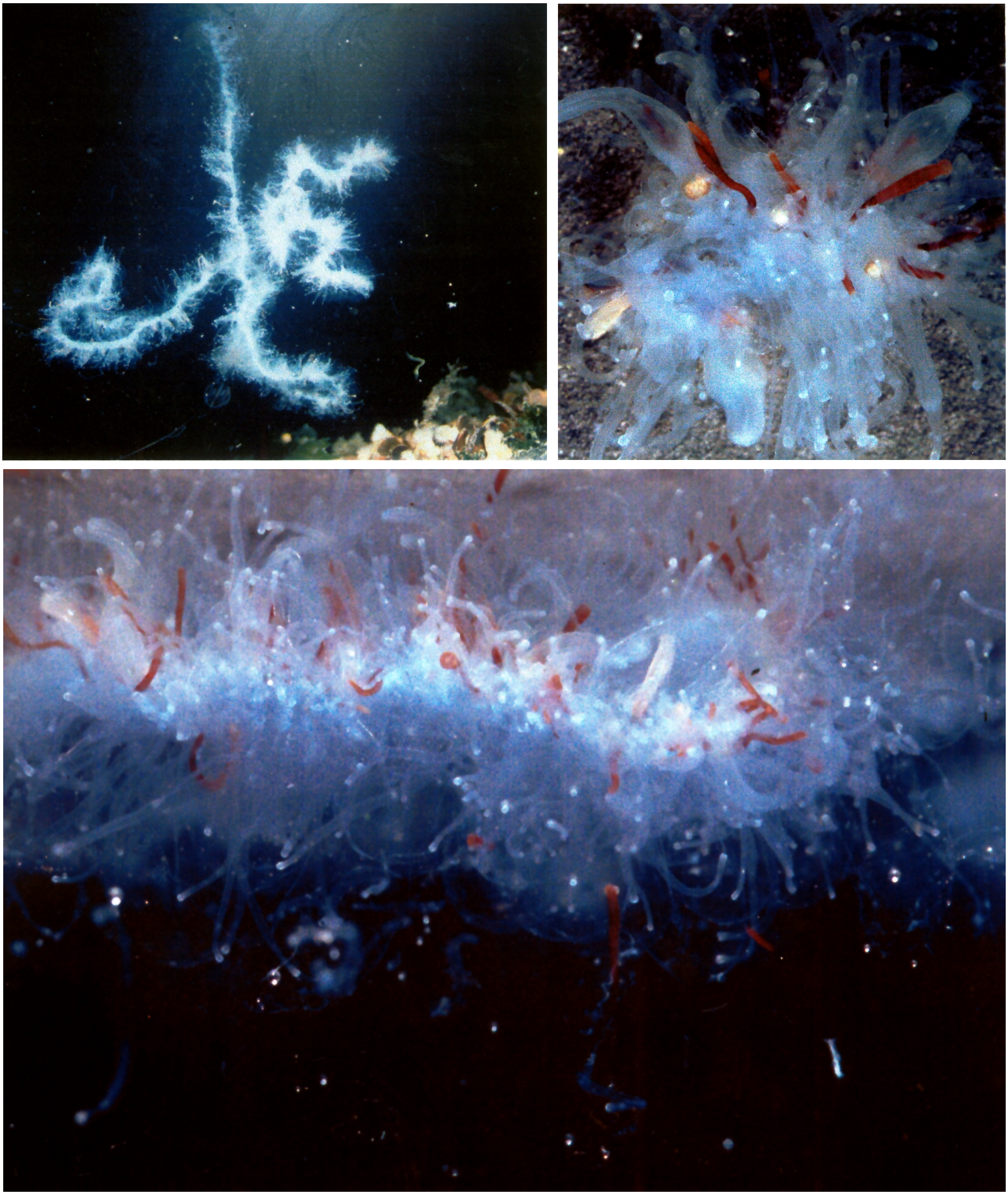

Fig. 3. *Apolemia uvaria* collected from the surface water. Top left: A whole colony with the stem contracted showing the typical irregular shape. Top right: Closer view of a cormidium group, clearly showing the two types of palpons (brownish and transparent) and a few gasterozooids. Bottom: A closer view of a section of the colony showing the typical appearance of a continuous mass of palpons and a few gasterozooids. All photos by Alf J. Nilsen.

(probably) the case for *Salpa fusiformis* after the main invasion in 1955 (Brattström 1972), when the occurrence in some fjords early the following year was explained by overwintering. Advective transport from the North Atlantic Current in the coming years is also highly possible. The historical data on *Salpa fusiformis,* reported by BRATTSTRÖM (1972) indicates inter-annual variation in influx of water rich in salps. The underlying physical mechanism is the variable amount and pathway of the North Atlantic Current, but this does not explain why the main advected species this time was *Apolemia uvaria,* other times *Salpa fusiformis.* Has there been a change at the community level in the pelagic ecosystem in the Northeast Atlantic or is there a change in the geographical origin of the North Atlantic Current during the last few decades, perhaps related to the large-scale climatic change? We cannot give any answer at present and leave the question open, hoping for increased research in this field of science. We have made a check of earlier zooplankton samples from the Svinøy transect and found remains of *A. uvaria* from April 1996. Thus, immigration to Norwegian waters might be a fairly common process, although a mass immigration must be a seldom event.

FUTURE RISKS OF INVASIONS OF HARMFUL ANIMALS FOR MARINE FARMING

Farming of marine animals in the sea will always be open to an exposure of unwanted biotic and abiotic factors such as toxic algae, parasites, stinging jellyfishes, and chemicals disposed in the water. Problems with stinging jellyfishes are not new to the salmon farmers. As late as early autumn 1997 there was an invasion of the scyphomedusa *Cyanea capillata* (L.) in the Lofoten area south of Senja, that time only causing marginal losses. However, *C. capillata* has been a real threat for the salmon farmers, with irregular invasions in the area from Hitra to Altafjorden (Karl Tangen, pers. commn) and Scottish fishermen in Loch Fyne got lots of *Cyanea* in their nets this summer (Jack Matthews, pers. commn). The ephyra stage of this species and the other common scyphomedusa, *Aurelia aurita* (L.), caused heavy losses in Søgne in southern Norway in 1994 and 1995 (Karl Tangen, pers. commn). These tiny organisms (a few mm diameter) stung the fishes in the gills when passing with the respiratory water, thereby destroying the epithelium and causing suffocation. Shetland fish farmers experienced the same problem with ephyrae and small medusae of *A. aurita* in winter/spring 1997 with considerable losses (Steve Hay, pers. commn). An interesting theory is that the polyp stage is prevalent on the cage structures and even might be able to utilize the food waste (Steve Hay, pers. commn). Adults of *C. capillata* represent the most common source of invasion problem for the Norwegian salmon farmers. Their many thin and long tentacles (up to 10 m) are easily torn apart from the medusa and can then flow into the fish cages, causing heavy losses. Mass occurrence of the small narcomedusa *Solmaris corona* HAECKEL in Shetland waters in August/September 1997 also caused problems for salmon farmers and at least one farm lost its whole stock (Steve Hay, pers. commn). This medusa is oceanic, with a southerly distribution (RUSSELL 1953), and its occurrence indicates hydrological shifts with upwelling of Atlantic water (Steve Hay, pers. commn). A heavy loss of local character was also caused by mass occurrence of the lobate ctenophore *Bolinopsis infundibulum* (O.F. MÜLLER) in May/June 1986 on the Møre coast, where three farmers lost all their stocks (Karl Tangen, pers. commn). In this case clogging of the gills was probably the direct cause of death for the salmons.

Thus, we can see two possible sources for future invasion problems for the marine farmers, (1) mass invasions of oceanic species transported by the North Atlantic Current and (2) blooming of local neritic species. Mass occurrence *per se* will not cause a problem. The typical high abundance of *Aurelia aurita* is an annual summer event in Kattegat and Skagerrak, without causing such problems. This species is most dangerous in mass occurrence as small individuals (e.g. ephyra stage), because of their ability to pass the net and causing suffocation as described above. Adult medusae with their short tentacles will be efficiently kept outside the fish cages. The key factor is the size and fragility of the invading species. The oceanic species hitherto causing problems was either small (*Solmaris corona,* ± 15 mm, RUSSELL 1953) or was easily broken up into small fragments (as for *Apolemia uvaria*), thus making the net of the fish cage an inefficient hindrance. The risk of getting local production of ephyrae in the fish cages as suggested by Steve Hay (pers. commn) is difficult to evaluate but should be considered a real possibility. In addition to the two common scyphomedusae *A. aurita* and *C. capillata,* we have many species of mainly small hydromedusa that might find the net of the fish cage a favourable environment for their polyp stage and such establishments can thus cause local blooms of small medusae. At least one occasion of fishkill by such medusae is known from Shetland, where *Phialella quadrata* (FORBES) was involved (Steve Hay, pers. commn). Reports on the mass occurrence of scyphozoan ephyrae in 1994/95 also included observations of high abundance of this type of jellyfishes (Karl Tangen, pers commn).

Species differences in nematocyst morphology and toxicology among cnidarians and in morphology and physiology among cultured species impose that the sensitivity for stinging will be specific for each invader/victim combination. Cnidarian species that have a potential impact on cultured species by occurring in high abundance, being of the right size or very fragile to get into the net cages, should therefore be used in encounter experiments with the different cultured species in order to separate between harmless and dangerous species. To be better prepared for the next invasion, research within this field should be initiated before the problem occurs.

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