The 1993 collapse of the Lake Kinneret bleak fishery

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Abstract Bleak, Acanthobrama terraesanctae Steinitz, constituted an important fishery in Lake Kinneret, Israel, accounting for 60% of the total commercial harvest, but less than 10% of the total fisheries income for the entire lake. The market demand of 900–1000 t annually has maintained relatively constant harvest pressure since the 1970s. The fishing season of 1992/93 was the last time bleak were harvested commercially. In 1993/94 the fishery collapsed; less than 10% of previous harvests was caught, and most fish were below commercial size. An overview of the bleak fishery during the past 60 years is presented, with evidence indicating that the collapse was the result of two interdependent events relating to harvest-induced stress: (i) a long-term shift in harvested fish size (age) that began in 1982; and (ii) two consecutive seasons of overharvest that led to the depletion of 2–3 year classes and the excessive recruitment of young-of-year of a single year class.

Introduction Since the establishment of Israel’s National Water Carrier with Lake Kinneret as its principal reservoir in the 1960s, the Lake Kinneret ecosystem has been the focus of extensive management and research programmes. Lake Kinneret, the largest freshwater lake in the Middle East, is situated 210 m below mean sea level in the northern part of the Afro-Syrian Rift Valley. Lake Kinneret is a warm monomictic lake, with winter homeothermal temperatures between 12°C and 14°C and maximum summer temperatures approaching 30°C (Hambright, Gophen & Serruya 1994). Typically, epilimnetic concentrations of total phosphorus and nitrogen (sum of ammonia, nitrates, and organic nitrogen) range between 13 and 28 µg L⁻¹ P and 0.4–0.9 mg L⁻¹ N (Berman, Yacobi & Pollingher 1992). The lake is highly productive with mean annual chlorophyll concentrations of 250–650 mg m⁻² and mean annual primary production of 438–840 g C m⁻² year⁻¹ (Berman et al. 1992; Berman, Stone, Yacobi, Kaplan, Schlchter, Nishri & Pollingher 1995). Consequently, the hypolimnion is typically anoxic.
during May–December with high H₂S concentrations. Lake Kinneret is generally considered naturally meso-eutrophic and stable, although the recurrence of mass developments of cyanobacteria (Aphanizomenon and Microcystis) since August 1994 (Berman 1995) are indicative of changes in trophic state.

Although phytoplankton biomass and production fluctuated little prior to 1994, zooplankton biomass declined by ~50%, from an annual mean of 42 g m⁻² in 1969 to 18 g m⁻² in 1991 (Gophen 1995). The decline, linked to changes in both species and size composition, was attributed to increased predation by zooplanktivorous fish (i.e. increased fish abundance or biomass) (Gophen, Serruya & Speratau 1990a; Gophen, Serruya & Threlkeld 1990b). Although the record of decline in zooplankton biomass is indisputable, the link to increasing fish abundance or biomass lacks definitive evidence. There are no suitable long-term data on Lake Kinneret fish standing stocks. Nevertheless, the position that harvest (fishing) pressure on the dominant fish in Lake Kinneret (bleak) should be intensified with the aim of reducing their population size to reverse the decline of zooplankton biomass has been repeatedly stated (Gophen 1984, 1985, 1993). A resurgence of this position occurred following the 1993 collapse of the Kinneret bleak fishery (Gophen 1996).

The Kinneret bleak fishery

Kinneret bleak (also known as Kinneret sardines and as Lavnum), Acanthobrama terraesanctae Steinitz (= Mirogrevex terraesanctae terraesanctae) are relatively small and short-lived cyprinids (maximum total length [TL] = 250 mm; natural lifespan 3–8 years) (Goren, Fishelson & Trewavas 1973). Bleak are iteroparous with an extended winter–spring spawning period lasting from November until March. During the spawning season, bleak form dense schools near to the shore, dispersing eggs into the water which are fertilized and which subsequently settle and attach to rocks in 10–15 cm of water (Gafny, Gasith & Goren 1992).

Bleak have always been part of the Kinneret fishery (Reich 1978). In the 1930s, less than 100 t year⁻¹ of bleak was harvested (Ricardo-Bertram 1944), but this amount gradually increased over time, stabilizing at an annual average of about 1000 t (Fig. 1). As most bleak are canned, the annual harvest (apportioned evenly among three fishing vessels) is controlled principally by the canning industry. During the 50-year period prior to 1991, bleak constituted about 60% of the total harvest from Lake Kinneret, but because of the low market value, the bleak fishery has generally contributed less than 10% of the US $5 million annual income from Lake Kinneret fisheries (Ben-Tuvia, Davidoff, Shapiro & Shefer 1992). For a detailed overview of both the historical and modern-day fisheries of Lake Kinneret see Ben-Tuvia et al. (1992).

Throughout the history of the bleak fishery, there has been little need for regulations governing harvest, with the exception of the 120 mm TL minimum length imposed by the cannery (Reich 1978). However, Davidoff (1982) recommended an increase in the minimum size to 130 mm TL because the bleak fishery was operating near the maximum sustainable yield (MSY) and the survival rate was low. Moreover, the bleak harvest comprised many small individuals, between 90 and 180 mm TL (Fig. 2), with > 30% too small for the cannery. Although the minimum legal size was not changed, the purse seine fishermen voluntarily included a panel of larger-mesh net (bunt) in their seine, beginning with the 1982/83 season, to allow smaller fish to escape before the seine was hauled in. In the nine fishing seasons
since the addition of the large-mesh bunt, τ 95% of the bleak harvested were 120 mm TL or larger and the mean and modal sizes of the harvest increased to 145 and 135 mm TL, respectively (Fig. 2). During the 1991/92 and 1992/93 seasons, the mean sizes of the harvest were 155 and 150 mm TL, with modal sizes of 155 and 140 mm TL, respectively.

The bleak fishery collapse

In the 1970s and 1980s, during which the market demand and harvest rates of bleak were relatively constant, Davidoff’s (1982) assessment of bleak population dynamics was practically ignored: the bleak fishery was considered stable (Ben-Tuvia et al. 1992). However, with apparently little warning, the condition of the bleak fishery declined suddenly after May 1993. There was no commercial harvest in the 1993/94–1995/96 seasons because the bulk of the catch was < 120 mm TL.

It is believed that the collapse of the bleak fishery was brought about by two interdependent forms of harvest-induced stress. The first stress to the bleak population was in the form of the shift to larger and hence older individuals in 1982/83 (Figs 2 & 3). The shift to dependence on larger and older fish was not in itself a harmful change for the fishery. On the contrary, such practice has long been recognized as a means for increasing the production and general value of a commercial fishery (Lackey & Nielsen 1980). However, a reduction in total harvest rates did not accompany the size shift and this caused problems. Davidoff (1982) predicted that a drop in harvest by as much as 46%, following an increase in minimum fish size harvested, would require new quotas. Unfortunately the old quotas, totalling about 1000 t annually, remained intact. Consequently, during the 7 years following the addition of large-

mesh bunts to the purse seines, harvest pressure on older fish, especially 3- and 4-year-old individuals, intensified and the proportion of 1-year-old fish in the bleak harvest gradually declined.

For reasons that are still unclear, the harvest of 1991/92 increased by 55%, from a 10-year mean of 955 t to 1478 t (Fig. 1, inset). [Note that this seasonal increase is obscured using annual totals.] It is now evident that this high catch in 1991/92 constituted overharvest of the older individuals and resulted in virtual elimination of the 1988/89 and 1989/90 year classes.
Fish abundance in Lake Kinneret was reduced to an eight-year minimum of 10–15 million individuals by April 1992 (Kalikhman & Walline 1994).

The harvest of 1992/93 was typical, with 891 t of bleak harvested, only 5% below the previous 10-year mean. The range of sizes harvested was similar to that in the previous year, and although the mean and modal sizes were slightly smaller than in 1991/92, they were still substantially larger than in the 1982/83–1990/91 period. Clearly these fish belonged to the 1990/91 year class or an earlier one. As in the previous year, high harvest rates in 1992/93, predominantly of a single year class (1990/91), resulted in a single year class (1991/92) dominating the lake’s population. The only real difference in the outcome between the 1991/92 and 1992/93 seasons was that the former left behind an exceptionally large year class. With the great success of the 1991/92 year class, few bleak were able to reach commercial size. Preliminary analyses of the subsidized harvest of 1995/96 indicate severe stunting in the population as the modal size of the catch was 105 mm TL and, according to scale reading, many of the fish appeared to be 2 or more years old (J. Shapiro, unpublished data).

Discussion

Various hypotheses for the bleak fishery collapse have been proposed. However, government policy to revive the fishery was based on only one hypothesis, which has not been thoroughly examined. Three basic tenets underlie this hypothesis and the amelioration programme: (i) the long-term decline of zooplankton biomass since the early 1970s was directly related to increasing predation pressure by bleak and their biomass must, therefore, be reduced (Gophen 1985, 1993); (ii) the winter floods of 1991/92 and the subsequent 4 m increase in water level...
allowed for increased spawning efficiency, and thereby led to exceptional recruitment in the
1991/92 bleak year class (Kalikhman & Walline 1994), which was aided by; (iii) heavy adult
mortality because of record low water temperatures of that winter (Gophen 1996). It was
suggested that the combined effect of these factors – low food, high reproduction, and loss of
adults – yielded a very large population of small, sub-commercial-sized bleak. In an effort to
restore the fishery, the Israel Agriculture Ministry adopted a programme in which fishermen
were paid to harvest these small (<120 mm TL) bleak during the 1994/95 and 1995/96 fishing
seasons. Although proponents of the plan recommended 1000 t be harvested each year, only
450 t were removed during the 1994/95 season; 1000 t were removed during 1995/96.

In addition to the failure to identify overharvest as the likely cause of the bleak fishery
collapse, there are other problems and inconsistencies with the hypothesis outlined above.
Firstly, there are no data available linking the long-term changes in Lake Kinneret zooplankton
with increases in fish standing stocks. A wealth of literature can attest to the strong influence
of fish on zooplankton assemblages. However, persistent reductions in zooplankton biomass
are not common among the documented impacts upon fish of shifts in species and size
composition of zooplankton assemblages or changes in zooplankton morphology, behaviour,
and gene frequencies (Hurlbert & Mulla 1981; Lazzaro 1987; DeMelo, France & McQueen
1992; Hambright 1994). Moreover, using a relatively long-term series of acoustic assessments
of fish abundance in Lake Kinneret, Walline, Pisanty & Lindem (1991) concluded that there
was no evidence of increased fish abundance from 1981 to 1990, a period in which zooplankton
biomass declined by 45%.

It was considered that the long-term zooplankton decline was, as indicated by Gophen
(1989), because of fish predation. However, it is possible that the predation pressure may have
increased, not because of increased fish abundance or biomass, but because of an increase in
fish turnover rate resulting from fishery practices. Few parameters were sufficiently well
measured on a long-term basis in the Lake Kinneret fishery to allow accurate calculation of
turnover rate. Nevertheless, a rough estimate of relative turnover rate of the Kinneret fishery
can be made using total catch data, similar to that shown for bleak in Figure 1. Harvest of
total fish biomass in Lake Kinneret has increased in modern times, mostly through improved
fishing gear and techniques, while the average size of individual fish has declined (Gophen,
Drenner & Vinyard 1983; Ben-Tuvia et al. 1992). Available data do not allow for a precise
description of the decline in body size, but there is strong anecdotal evidence that fish today
are smaller. An obvious conclusion derived from these two observations is that the life cycle
of fish in the lake has, in effect, become shorter, reproduction is from progressively younger
individuals, and overall turnover of the populations is higher – all well-documented symptoms
associated with overharvest or MSY-based harvest (Larkin 1977). Because mass-specific
ingestion rates decrease with increasing fish size (Peters 1983; Gerking 1994), a logical
deduction is that predation pressure on zooplankton in Lake Kinneret has increased over time
because fish size decreased and fish turnover rate increased.

Recruitment of bleak young-of-year (YOY) following the 1991/92 spawning season was
exceptionally high. Pelagic fish abundance (assumed to comprise > 90% bleak) rose to in
excess of 200 million individuals, the highest recorded in the last decade (Kalikhman &
Walline 1994). A second inconsistency with the government-adopted scenario is that it identified
this exceptional 1991/92 year class as a cause of the bleak fishery collapse rather than a
symptom of overharvest leading up to the collapse. The reason for the increase was hypothesized to be increased availability of spawning substrates and increased egg hatching success resulting from the unusual 4 m rise in Lake Kinneret water levels that year (Kalikhman & Walline 1994). However, available data suggest that the increase may have been related to a lack of competition from previous year classes of bleak, as only a modest bleak population (mostly the 1990/91 year class) was present during the 1991/92 spawning season. Unfortunately, little is known about recruitment of bleak after hatching, although post-hatching mortality could be as important to year-class strength as egg hatching success, because the number of eggs laid each year is far in excess of what is needed (Gafny et al. 1992). Moreover, observations made during the 1991/92 spawning period suggested relatively low overall bleak egg production, as there were unusually long periods (2–4 weeks) during winter in which no eggs were found at the traditional spawning sites (A. Gasith, personal communication). Hence, it is concluded here that exceptional conditions for YOY recruitment, and not hatching success, most likely led to the large 1991/92 year class.

Given today’s awareness of the delicate relationship between human activities and environmental quality, especially with regard to lake eutrophication, it is perhaps too easy to implicate fish in water quality deterioration. However, in attempts to influence government policies, great care must be taken not to detract from government’s confidence in science by citing equivocal and untested hypotheses without adequate guidance. Granted, the government amelioration programme for the Lake Kinneret bleak fishery was based heavily on speculation, as few data were initially available. As such, the adopted amelioration programme of removing small bleak continued to apply the heaviest pressure on the larger members of the population – a similar situation to that before the collapse. Now, and with hindsight, it is apparent that given the potential role of overharvest in the collapse, the least complicated plan of action would have been to stop all bleak harvest (perhaps for at least 3 years), followed by a reduced harvest programme allowing increased survivorship to older ages. Reduced mortality is still the best remedy for overexploited fisheries (Myers, Barrowman, Hutchings & Rosenberg 1995).

Conclusions

The following recommendations for management and future study are offered.

- Overall management effectiveness in the Lake Kinneret fishery can be improved by switching to seasonally based, rather than annually based, data collection and management.
- Management effectiveness in the Lake Kinneret ecosystem as a whole will benefit from increased study of fish population dynamics, especially with regard to interactions between fish and zooplankton at the level of production dynamics.
- The bleak fishery in lake Kinneret will benefit from a harvest programme that favours lower turnover rate and higher stability in the population: this translates into reduced harvest of large individuals. The fishery should be heavily reduced, as lower mortality will enhance recovery.
- Subsequently, the fishery could continue using the net and bunt mesh sizes currently in use, but with a cut in overall harvest of at least 25% (the actual quantity must be determined empirically). Not only will such a harvest programme improve the bleak fishery in general,
but the lower turnover rate in the bleak population could translate directly into improvements at the lower trophic levels.

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