Towards a methodology for assessing whether the UK populations of allis and twaite shad are at favourable conservation status.

Stage 1 Task Report

Review of shad monitoring in the UK, other EU countries and the USA
March 2001

Contents

1 Current approaches to Favourable Condition Assessment of shad in SACs

1.1 Introduction

There is not currently a routine monitoring programme that can be used to determine the favourable condition of shad in UK rivers. In 2000, the Environment Agency (EA) carried out juvenile monitoring in four rivers where twaite shad populations are known to exist: Severn, Wye, Usk and Tywi. In addition, catch data from estuarine netsmen has been collected for many years. Monitoring for shad does not take place in other UK rivers.

Shad have been observed migrating through fish passes in many UK rivers, but fish counters are not currently used to monitor shad populations on SAC rivers. This is in part due to an inability of current hydroacoustic techniques to deal with large shoals of migrating fish, as occurs when shad migrate upstream to spawn.

In other EU countries and the USA, approaches to shad stock assessment are different, and in some cases more advanced, than in the UK. Shad populations in France and USA are commercially fished. As a result, catch per unit effort (CPUE) of commercial fisheries is available and serves as an indicator of shad condition in a river system. Fish counters fitted with viewing windows and video equipment or automatic fish counting software are used in France to monitor shad populations. Another technique used in France to monitor shad populations, is counts of spawning adults at spawning sites.

Counting spent corpses at spawning sites is not used to assess shad stocks. Monitoring of shad eggs to assess population condition is also a less-favoured approach.

1.2 Fishery-dependent monitoring

1.2.1 Commercial fisheries

1.2.1.1 UK

In the UK there is no routine monitoring of shad caught as a bycatch of in-river fisheries, except the work undertaken by Dr. Miran Aprahamian of the EA. Catch data of adult shad, caught as a bycatch by the putcher rank fishermen in the Severn Estuary, was collected by Aprahamian from 1979 until 1998. The putcher rank nets in the Severn have now been almost entirely bought out. Consequently, data from commercial netsmen may not be available for more than a few years (Evans, pers. com.).

Shad catches are not routinely collected from netsmen in the UK, although studies show that it would be relatively easy to instigate a method of collecting information on shad catches. During an R & D Project investigating the spawning status of shad in Southwest England, Hillman (2000) observed that shad are often caught by salmon/seatrout netsmen

as a bycatch of salmonids. A pilot survey of shad-catches among netsmen was met with considerable success; the use of a Shad Recording Form for catch returns showed that shad can be monitored on commercially fished rivers. At present the EA keeps salmonid net catch information on an Oracle database. It is not current policy to include shad in this database, but it may be possible to amend the database to incorporate shad catches (Evans, pers. com.).

1.2.1.2 Other EU Countries

France
In France, the management of migratory fish is done on the scale of the catchment by a management board, which is composed of fishermen, administrators and elected officials (Boisneau, pers. com.). At the national level there is a general program, which considers the big picture for shad conservation in France, including the major objectives in terms of the restoration of migratory fish. Final decisions are made at the catchment level (Boisneau, pers. com.). Commercial fisheries in France principally take allis shad rather than twaite, allis shad being the most abundant species (Boisneau and Sabatie, pers. com.).

In the Gironde-Garonne-Dordogne catchment, France, CEMAGREF (Bordeaux) undertake a yearly estimate of commercial net catch data for shad (Cassou-Leins and Sabatie, pers. com.). Similar annual estimates of commercial net catches are made on the Loire (Sabatie, pers. com.) and the Rhone (Menella, pers. com.). Indices of abundance have been created based on commercial catch data from the last 20 years and catch per unit effort (CPUE) is compared between years (Guerri, pers. com.).

In the Gironde-Garonne-Dordogne catchment the Superior Council of Fishing (CSP) collects catch information from 4,000 river fishermen (amateurs and professionals), who declare their catches daily, indicating fishing method and species taken (Changeux, pers. com.). The declaration of shad is obligatory in the public domain of the river. A similar statistical survey of commercial fishermen catches in estuaries and coastal waters, is undertaken by the Regional Centre of Processing the Statistics of maritime fisheries (CRTS) [Changeux, pers. com.].

Portugal
In Portugal commercial fisheries exist in freshwater but catch statistics are not reliable (Raposo de Almeida, pers. com.). There is no monitoring programme of Portuguese shad populations.

Ireland
There is no routine monitoring programme developed as yet in Ireland (King, pers. com.). Investigations in 1999 and 2000 revealed that snap-net fishermen, who operate in the estuary downstream of Carrick on the River Suir, frequently catch shad as a by-catch of salmon. This technique involves the suspension of a simple panel of large-mesh net approximately 20 m in length between two small canoe-like boats, known as cots. One or two persons may man the cots. In either case, the boat must be handled using a paddle

while the head- and bottom-rope of the net are held in the hand. Fish contacting the net will be sensed through the ropes and the fishermen can manipulate the ropes in such a manner as to close or 'snap' the net shut, retaining any fish inside. Fishing is done by drifting with the ebb or flood current (Central Fisheries Board [CFB], 2001).

In spring 2000 a series of experimental netting operations were undertaken specifically for shad, prior to commencement of the open netting season for salmon. Netting commenced in mid-April and continued into June in order to try and secure adult fish at various stages of the spawning run. In each such netting effort the fishing was done by the commercial netsmen, who were accompanied by officers of the SRFB (Southern Regional Fisheries Board). Any shad encountered were handled by the SRFB officers, who collected information on length, weight and a sample of scales to permit ageing of the fish. A total of 8 snap net fishings, involving 57.5 hrs of sampling yielded four twaite shad only, representing a very low level of return for a substantial sampling effort. It is possible that the mesh size used in the R. Suir snap nets may permit smaller fish to escape.

Trials using different sampling methods will be made by the CFB this year (2001) [King pers. com.].

1.2.1.3 Eastern Europe

The River Danube, which flows through Romania, Ukraine, Bulgaria, and Yugoslavia, has a pontic shad (*Alosa pontica*) fishery of about 5,000 fishermen (Navodaru, pers. com.). At present there are both fishery-independent and fishery-dependent monitoring programs, although there is still a need for an integrated monitoring program (Navodaru, pers. com.). They are related to administrative and research needs, and are spread between institutions, research institutes and universities (Navodaru, pers. com.).
The fishery-dependent monitoring falls within the jurisdiction of the Danube Delta Biosphere Reserve Authority (DDBRA). The DDBRA administrates the Danube Delta; there is another organisation-the National Romanian Waters Agency (NRWA) that administrates the Danube River upstream of the delta. All fishermen have to report monthly;

- the size of catch,
- place of fishing,
- number of days of fishing,
- number of fishermen,
- boats and gears used.

The main constraints on fishery-dependent monitoring are incomplete data recording and the poor credibility of information (Navodaru, pers. com.).

1.2.1.4 USA

In the USA fishery-dependent monitoring programs for American shad are mandatory in nine different states on the Atlantic coast. The minimum information recorded, as set out in the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Management Plan for Shad and River Herring (1999), is as follows;

- location, target species, and season of fishery or fisheries involved;

- gear and gear specifications used in the fishery (eg gillnets, 4.5" mesh size);
- an estimate of pounds or numbers and size or age of American shad taken per unit of effort in the fishery (eg, lb. per trip), as well as an estimate of total American shad bycatch in the fishery;
- an estimate of how long (eg, years, months, weeks) American shad bycatch has occurred in the fishery.

In cases where excessive alosine bycatch is documented, the involved jurisdiction(s) are instructed to make such documentation available immediately to the ASMFC Technical Committee, Advisory Panel, and Management Board. The Technical Committee examines trends in estimated bycatch annually.

The ASMFC have estimated biological reference points (overfishing definitions) for American shad in seven Atlantic coast rivers. The Management Board monitor mortality rates as a result of fishing, which if too high (ie overshooting the target mortality rate), results in the imposition of stricter fishing regulations. The conservative overfishing definition of F_{30} (the mortality rate that will result in 30 % of the maximum spawning potential of an unfished population) serves as a reference point that is not to be exceeded in any given year. It is not a target for commercial or recreational fisheries to achieve, nor is it suitable for rebuilding depleted stocks (ASMFC, 1999).

1.2.2 Recreational Fisheries

1.2.2.1 UK

Anglers in many UK rivers and estuaries catch shad. Collection of this data and assessment of catch per unit effort is not currently undertaken. The EA monitor the number of rod-caught salmonids and keep catch returns on a national database. There is not a similar recording scheme for shad at present.

1.2.2.2 Other EU Countries

France

Guerri (pers. com.) described a 'notebook of fishing' produced in France by the higher Council of Fishing. This is a statistical tool to catalogue the captures of the professional river fisheries and recreational fishermen. In the Garonne and Dordogne, this notebook can serve as a means of estimating shad abundance. The notebook has been used for two years, so a long term data set is not yet available. But when data has been collected for a longer period, a data set obtained from fishery-dependent monitoring will provide a means with which to compare fishery shad catches between years. In contrast, Boisneau (pers. com.) thought that shad catches by rod/amateur fishermen in French rivers are poorly documented at the present time.

Ireland

Over the past 15 years, substantial numbers of shad have been captured by rod-and-line angling on the R. Barrow at St. Mullins, Ireland. In 1999, by way of a trial of shad monitoring methods, angling was carried out at Carrick-on-Suir. No shad were caught in

1999 via angling, as part of a survey on the River Suir. In 2000, CFB decided that rod angling would not be used as a method for sampling adult shad, due to low net returns and unsuitable environmental conditions. However, Duchas (The Heritage Service) liased with the CFB and SRFB and assisted in data collection at a large competition, held annually by the local angling club in St. Mullins, on the River Barrow. Length, weight and scale data was collected from fish captured during the competition (CFB, 2000).

1.2.2.3 USA

In 14 Atlantic states of the USA, monitoring of American shad via recreational landings, catch and fishing effort takes place. This monitoring is undertaken biannually in the Connecticut River. Age, sex ratio, and fishing effort (hours fished) is noted, until the annual catch exceeds one thousand fish. In all other states, recreational landings, catch and fishing effort is monitored every five years.

1.3 Fishery-independent monitoring programs

1.3.1 Research surveys: netting for adults

Although surveys that target adult shad are not routinely carried out in the UK, there are a few routine surveys with the potential to catch shad. Fish surveys have been undertaken by the EA since 1992, in the Thames estuary, from the estuary foreshore (Colclough, pers. com.). The work is carried out at six sites between Teddington and West Thurrock, using two seine nets (35 and 50 m), a 2 m beam trawl and a kick-sampling net. Sampling is carried out twice per year, once in May/June and once in September/October. Shad have not been detected by these ongoing surveys, but Colclough attributed this to the sampling location being too far upstream; fishermen downstream of West Thurrock have caught shad.

In the Garonne estuary, France, a survey is carried out monthly by sampling at 12 stations (at the surface and on the bottom)[Rochard, pers. com.]. This has taken place since 1980. In the Loire basin adult sampling has been carried out using methods similar to commercial fishing practises (Boisneau, pers. com.). This work has been done in response to research needs, rather than on a routine basis. In the Garonne and the Loire environmental information, such as flow strength and water temperature is collected when sampling is carried out.

In the Danube adults from the migratory stock are caught for research purposes using drift trammel nets (Navodaru, pers. com.). This sampling is not routinely undertaken: it is carried out by research institutes to gather specific information for studies of stock demography; length, weight and age of shad is recorded.

1.3.2 Counts of spawning adults on the spawning site

When shad spawn they make a characteristic splashing noise with their tails. In France this spawning behaviour is used to count the number of adults (or pairs of adults) on a spawning ground. The technique is being developed, so that estimates can be made of the

spawning population of a river. This approach to shad monitoring has not yet been adopted in other countries.

1.3.2.1 Methods

In the Garonne the number of shad spawning downstream of the Golfech power station, has been determined each year since 1985 by counting the egg-layings of shad on the spawning grounds (eg Belaud and Carette, 1998; Belaud and Carette, 1999). Each movement is characterised by the whirling stroke of a male and female during egg-laying (Cassou-Leins and Cassou-Leins, 1981); the egg-laying is perceptible from the banks by the noises (and sometimes by sight) of spawning shad (Belaud *et al*., 2000). It is thus possible to estimate the number of spawners by counting the number of bulls (males) on the basis that:

1. The spawners reproduce on only one spawning ground;
2. Only one female is paired to a 'bull';
3. The sex ratio of fish on the spawning ground is 1:1;
4. Each female lays on average 7.5 times (an average derived from Cassou-Leins and Cassou-Leins (1981) and Dartiguelongue (1996)).

On the Garonne the main spawning sites are at Agen and La Magistere; this is where the counts are made of spawning adults. The site at Agen is such an important spawning site, it has been classified a Natural Reserve for Allis Shad. Counts have been made for 20 years using acoustic recordings (tape recorder started automatically by a programmer) [Cassou-Leins, pers. com.]. Agen and Magistere have been the subject of nightly surveys since 1981 and 1989, respectively. These sites have been equipped since 1989 with recording apparatuses. These function from May to July, and are operated in situ at least twice per week (Belaud *et al*., 2000).

Spawning takes place exclusively at night, between 0h and 5h, with a maximum frequency between 2h and 3h 30 (Cassou-Leins and Cassou-Leins, 1981; 1990). Searching is based on observations, carried out either from drifting boats or from listening stations in the banks. The known spawning grounds of shad are favoured, but the whole of the Golfech-Agen section of the Garonne was prospected by exploiting all accessible areas (Belaud *et al*., 2000). Once indexed, the spawning grounds are manned and monitored directly, by the presence of posted observers, or indirectly by the use of sound recording systems (Troulhet, 1992). Direct hearing is more powerful; the mobility of observers is essential and the equipment at the sites is not fixed at one location.

On the Aulne, Brittany, Sabatie (pers. com.) has created a 'forced' spawning area, which concentrates all the migrants, enabling the calculation of an abundance index of the population. Work is being carried out in an attempt to link the number of fish passing the fish pass and the number of bulls on the spawning area. An evaluation of the sex ratio is also being undertaken. This will allow Sabatie to know the number of spawnings per fish and to deduce the spawning population. This approach will be adopted in other areas with similar characteristics.

1.3.2.2 Environmental and fluvial data

In order to formulate spawning stock estimates, French researchers collected environmental and fluvial data. The slope of the river, width and profile was used to calculate the wet surface area for various water levels (corresponding with various flows). The measurement of river profiles transversely, consisted of tracing the datum lines for various values of flow. Flow levels were either determined directly by a local gauging station, or by extrapolation between two stations flanking the profile being measured. The corresponding wetted cross sections were measured by planimetry. The mean velocities for each flow were calculated by dividing the value of flow by the corresponding wetted cross-section. For each profile, a range of points were thus obtained, generating a characteristic flow velocity (Belaud *et al*., 2000).

Hydrological and climatic data were obtained from various services in the Garonne. The environmental approach was supplemented by specific measurements at the Agen reserve: surface speeds were measured by a currentometer (Marsh McBirney model 200 flowmate_) and depths according to transverse profiles, using an echosounder installed on a boat.

1.3.3 Counts of spent corpses at spawning sites

It has been suggested that shad spawning stocks could be monitored by counting the corpses of spent adults at, or downstream of, the spawning grounds (Mainstone, pers. com.). This approach is not currently used, probably due to the low level of reliability that spent corpses would be detected. Garman (1992) found that in an experiment, *Alosa aestivalis* carcasses weighed down and placed in the James River (Virginia, USA), were transported downstream at an average rate of 986 m/h. Furthermore, shad may not die at the spawning site itself, or in the case of the iteroparous twaite shad, not at all.

1.3.4 Fish counters and adult trapping programs

1.3.4.1 UK

Although fish counters exist on many SAC Rivers throughout the UK, they are not designed to monitor shad. Shad have been, and continue to be, detected on some fish counters, as they migrate upriver. At Chester Weir on the River Dee, a trapping program, undertaken since 1991, has detected a total of three shad only (Davidson, pers. com.). Shad have not been observed on fish counters in Southern Region (Fewings, pers. com.), North West Region (Atkins, pers. com.) or North East Region (Rippon, pers. com.). Fish counters in Welsh region (Gough, pers com.), Midlands Region (Aprahamian, pers. com.) and South West Region (Hillman, pers com.) have detected shad, but monitoring does not take place, either because observations of shad are too infrequent or because technical restrictions prevent it.

Hydroacoustic counters
The detection of shad using hydroacoustic fish counters has been considered at the

Redbrook counter on the River Wye. At present, it is not possible to obtain quantitative population estimates from hydroacoustic fish counters because the technology is not suitable (Gough, pers. com.). The echo integration approach to hydroacoustic monitoring is not ideally suited to sideways counting and to riverine environments (Gregory, pers. com.). Echo integration is used to estimate the quantity of fish in the acoustic beam, allowing for overlapping echoes in the received signal, unlike the alternative technique of echo counting. This is done by connecting an echosounder to a device that accumulates the energy in the received signal (MacLennan and Simmonds, 1992).

Shoals can be identified and counted, as they have been in 1999 and 2000, and the relative size of the shoals measured by the amount of energy returned, but it is not yet possible to equate exact shoal size to the amount of energy returned. Although the timing of the migration is known (this varies from as early as March, to July), shoal sizes vary considerably, especially at different times during the migration period. At peak migration shoals are a lot larger. Gough (pers. com.) indicated that the variation in shoal size can be in the order of between 6 and 1000 fish. Above a certain size the shoal effectively saturates the counter, ie no additional increase in shoal size will increase the amount of returned energy that is recorded.

The amount of energy returned per shoal will also depend upon their distance from the beam and the orientation of the fish within the shoal. Two shoals of identical size may return very different levels of energy depending upon these criteria. Although it may be possible to categorize shoals on the basis of how much energy they return, it would be hard to justify the accuracy of such an approach to producing a population estimate (Gregory, pers. com.).

The techniques used for applying hydroacoustics to gathering quantitative data will be developed and improved over the next few years (Gough, pers. com.). Gregory (pers. com.) suggested that a project using video footage analysis to investigate the relationship between energy returned by shoals of shad and the size of the shoal, may provide a way of estimating shad spawning stock on the River Wye. The end product of such a study would be to produce confidence limits in shoal size estimates, based on the amount of energy returned by the shoal.

Resistivity counters

Resistivity counters have not been used in the UK to monitor shad. Like hydroacoustic counters, resistivity counters are not suitable for detecting shoaling fish such as shad because; 1) above a certain size the shoal saturates the counter, ie the maximum deflection is recorded, and 2) resistivity counters are built on Crump weirs and these are not designed to permit access to shoals of fish (Gough, pers. com.). Crump weirs, by definition have a small standing wave at the base that has been observed to delay or even prevent shad migration (Gough, pers. com.).

On the River Usk, Wales, where a population of twaite shad is known to exist, the resistivity counter at Trostrey, has not been in operation since 1997. The Gunnislake fish counter, on the River Tamar, Cornwall, has detected small numbers of shad migrating upstream (Hillman, pers. com.). The deflection in the electric field created by shad is

typically lower than for salmonids of similar body length. This may result in the failure of resistivity counter monitoring to detect shad, especially if deflection values below a threshold are discounted from video validation, as is the case with Gunnislake salmonid monitoring.
The identification of shad from video footage on the Gunnislake counter in 2000 was carried out as follows:

- Priority was given to viewing video-footage taken on days when water temperature exceeded 15 ^{o}C.
- Downward facing camera footage was viewed using fish counter deflection data to 'locate' fish events.
- Only fish above a deflection value of 30 were located on the footage.
- Fish above 40 cm total body length (calculated from a conversion factor based on screen length and position), that had clupeid characteristics (laterally flattened body and forked tail) were located on the surface-skimming camera footage.
- A deep body, deeply forked-tail and the position of fins enabled shad to be identified.
- The deflection, date, time, body length, flow data and water temperature were noted and a photograph was taken of the fish.

The detection efficiency of the Gunnislake counter for upstream migrating fish was estimated at 90% in 1993 (EA annual report, 1999).

1.3.4.2 Other EU Countries

France
Fish counters are used in France to monitor allis shad stocks on the Gironde-Garonne-Dordogne catchment (Belaud, pers. com.; Chanseau *et al*., 2000) and the Loire (Rancon, pers com.). On the Garonne, the counting of migrating adults is conducted by the Association for Migratory Fish Restoration on Garonne and Dordogne Rivers (MIGADO) and Electricite de France (EDF) [Travade *et al*., 1998].

The most common means of counting fish in fish passes is to capture them in a trap installed within the pass or at its outflow. The advantages include relatively easy installation, ease of identifying species and collection of biological data and the possibility of removing individuals for marking or use as brood stock. Disadvantages include the risk of injury or stress and the high maintenance and staff costs (Travade *et al*., 1998).

Resistivity counters have been developed in France but only a dozen have been installed (Gosset, 1986). Although the reliability of the counts has been shown to exceed 80 %, the major drawback is its inability to discriminate between species other than by their size (Travade *et al*., 1998).

Visual counts of fish swimming past a viewing window has the advantage of permitting the majority of species to be identified and continuously counted without handling them. This solution is time consuming and the use of video technology has proved to be a

feasible method for estimating fish passage. There are, at present, about a dozen permanent, video counting stations in France (eg on the rivers Garonne, Dordogne, Allier, Gave de Pau, Vilaine and Ariege). An automatic detection, counting and data processing system is the latest approach to fish pass monitoring in France.

Gironde-Garonne-Dordogne
There are hydroelectric power stations with fish passing facilities at Golfech and Le Bazacle on the Garonne, and at Tuilieres and Bergerac on the Dordogne. These stations are located on the middle part of this basin and the spawning grounds are located immediately downstream of these obstacles. At Bergerac and Le Bazacle the fish-passes are pool-type; the other two, at Golfech and Tuilieres, are fish elevators.
Counts are made using video recording techniques, from 1987 to 1998 at Golfech on the Garonne, and from 1989 to 1998 at Tuilieres, on the Dordogne. The principle of this technique consists of making an underwater viewing window, at a level section of the fish pass, where fish are filmed continuously using a lighting system, identified and validated (Travade and Larinier, 1992). The lateral view afforded by these windows is sufficient to allow the differentiation of species. Each glass window is about 1.5 m wide and 2 m high and overlooks a restricted passage (baffles or simple narrowing of the structure) with a maximum width of 40 to 50 cm (Travade *et al*., 1998). The counting area is illuminated to guarantee optimum visibility throughout the day.

Counting is facilitated with an automatic recording device developed specifically for these installations. Originally, the CERBERE system was used and developed by EDF-DRD, to include a video camera connected to a video recorder, which records over a long period at reduced speed and returns to normal speed when a fish enters the cameras' field of observation (Travade and Larinier, 1992). This system consists of a time-lapse video recorder running at very low speed (480 h for a 120 min video tape) and recording at normal speed when an external signal is generated by an image analyser (Travade, 1990).

An information processing system using specially developed software (Castignolles, 1995; Cattoen *et al*., 1999), replaced the traditional videotape recorders in 1998 (Chanseau *et al*., 2000). Adult shad are now identified and counted automatically by video systems at Golfech and Tuilieres (Rochard, pers. com.). The automatic detection system involves digitising each video image, segmenting the image to isolate objects (mainly fish), measuring certain characteristics of shape, identifying these objects (ie species identification if it is a fish) and counting them by dynamic tracking (Travade *et al*., 1998). Back lighting has been found necessary to avoid holes and outline erosion in the shape of the fish. The images are saved in binary code, compressed in real time and sorted on an optical disk. Automatic viewing is accomplished using standard PC microcomputers. Each file of encoded sequences is decoded and, after its connected components have been separated in a labelling stage, geometric parameters are extracted from the objects to be identified and are sent through a discriminant analysis classification process (Travade *et al*., 1998).

These operations are part of a dynamic process which tracks each fish while it is in the observation field in order to count it. Images are processed much faster than they have been recorded; one day of recording during peak migration can be processed in less than

30 min. During peak migration, fish frequently overlap each other, the computer consistently underestimates the number of fish and species identification becomes more difficult and less accurate. In such situations, a manually operated, computerised editing system has been designed to review the stored fish passage files and produce fish counts within a significantly shorter time (Travade *et al*., 1998).

In addition to fish counts, environmental information is recorded at the hydroelectric power stations, such as temperature, flow, turbidity, conductivity, pH, oxygen content and weather conditions, barometric pressure, rainfall and wind speed (Dauba, pers. com.).

Loire
On the Loire there are counting stations at Vichy and Decize (Rancon, pers com.). These stations, located approximately 600 km from the Loire estuary, control all of the shad migrating to the spawning grounds. The fish pass at Vichy is in front of a vertical viewing window; the fish pass at this point narrows and the fish swim between the pane and a visualization plate in front of neon tubes. The observation of fish through the pane makes it possible to determine the species and to measure the size. Counting is carried out all year, twenty-four hours per day, by video-recording from side cameras. The species are identified and counted by viewing the recordings.

The fish counter at Decize also consists of recording fish on video as they pass through a narrowed section of the fish pass. A trapezoidal chute upstream of the fish pass concentrates fish into a small space as they migrate through the pass. The base of the chute is white with black tape at 20 cm intervals; thus, a camera placed at the base of the chute enables fish to be filmed as they exit the pass. Recording at Decize is also carried out twenty-four hours per day, from the beginning of May until the beginning of July. A video surveillance device similar to that at Vichy will be installed at Decize in 2002 (Rancon, pers. com.).

Sabatie (pers. com.) indicated that fish passes for the trapping and counting of shad will be installed at Chatelraut (Vienne) and downstream from Maine (in the basin of the Mayenne, Sarthe and Loire).

1.3.4.3 Eastern Europe
No fish counter exists in the River Danube because there is no dam. Navodaru (pers. com.) studied the possibility of using a hydroacoustic counter to monitor the spawning population: he concluded that hydroacoustic techniques are not yet developed for use in large turbid rivers.

1.3.4.4 USA
Monitoring at fish passes features as part of the Interstate Fisheries Management Plan for American shad, river herring (*Alosa pseudoharengus*) and hickory shad (*Alosa mediocris*). Adult spawning stocks are assessed using a combination of mark/recapture studies, enumeration at fish passage facilities, catch-per-unit effort, and measurement of mortality and survival rates. At fish passes the methods by which monitoring takes place includes absolute counts, timed counts and electronic counting tubes.

Trapping of river herring and hickory shad takes place on some fish passes to evaluate fish length, age and sex. On Lamprey River, New Hampshire, annual samples of 150 lengths by sex are taken three times during the spawning runs (beginning, middle, and end). Fifty of the fish from each of the three samples are aged. On other rivers such as the Exeter River, NH, annual counts of the number of spawning adults returning to the fish ladder is made via timed counts or absolute counts, but length measurements by sex, and scales for ageing are taken in some years on an opportunistic basis.

1.3.5 Fry and juvenile surveys

1.3.5.1 UK

Dr. Miran Aprahamian of the EA carried out seine netting for juvenile twaite shad in the River Severn, in the years 1979-1981 and 2000. Information on adult shad was available from the putcher rank fishermen on the Severn, but recent net buy backs has meant that this form of monitoring is no longer available.

In 2000, a 2 mm micromesh seine net was used to undertake the juvenile (0+ and 1+) sampling. The net used was 30 m long, 2.8 m deep, with barrel leads spaced at 37 cm and floats at 32 cm. The netting takes place from the bank, although a boat is used to set the net. This sampling is carried out on an ebb flow during neap tides. Surveys were scheduled to take place once per month in July, August, September and October (ie 4 days), but the September netting was cancelled due to poor weather conditions (ie 3 days sampling took place). Netting took place at two sites on the River Severn at Framilode and Bullo. Each day took 5 hours to net the two sites (2.5 hrs per site). At each site 5 nettings were undertaken. Given that netting typically involved 4-5 people (Crundwell, pers. com.), the total netting effort for the 2000 juvenile sampling programme was:

- 20-25 man hours per day, excluding travel to the site (10 nettings)
- 80-100 man hours per year (4 days, 40 nettings)
- 2-2.5 man hours per netting.

Dr Miran Aprahamian analysed the juvenile shad samples: length (mm), weight (g) and age were measured.

1.3.5.2 Other EU Countries

Ireland

A routine survey for juvenile shad does not currently exist in Ireland. Investigations were carried out in 1999 and 2000 on the R. Suir and R. Barrow; a one-week survey was undertaken by CFB in late-September using a fine-mesh seine netting technique to sample for juvenile stages of a range of fish species, including shad, in the estuarine and tidal areas. Only one juvenile shad was encountered in the net hauls on the R. Suir. The timing of the survey, the potentially small size of the shad population and the possibility that young fish reside in more high-velocity areas in the centre of the river channel were suggested as reasons for the dearth of juvenile shad caught.

France

There is not a systematic program of sampling for juvenile shad in France (Boisneau, pers. com.), although in some catchments surveys are being carried out. Belaud (pers. com.) indicated that searching for juveniles is very difficult in large rivers such as the Garonne. Several attempts, using a variety of methods, have been made at sampling juveniles in the Garonne (Dauba, pers. com.).

In the Garonne, studies of recruitment are undertaken by CEMAGREF (Bordeaux) and INRA, to assess the strength of the seaward juvenile migration (Dauba, pers. com; Belaud, pers. com.). Sabatie (pers. com.) indicated that CEMAGREF undertake juvenile sampling of allis and twaite shad in the Gironde axis. An index of abundance is used to assess the interannual level of recruitment.

The sampling of fry has been carried out using a Bongo net of 80 cm diameter at the gape, 3 m long and 1 mm mesh size. The net is placed on the bottom and weighted and allowed to trail in the current (Cassou-Leins *et al*., 2001). Also used is a large scoop called a 'treoul'. This net is 1.2 m in diameter at the gape, 1.5 m deep and 8 mm mesh size. The net is fixed to the end of a handle of 5 m in length (Cassou-Leins *et al*., 2001). Netting is carried out immediately downstream of the spawning grounds on the edge of riffle sections (Dauba, pers. com.). The handle is either on the bank or on a boat, but netting is carried out in a standardized way (the unit effort of fishing can be defined by a sequence of 50 throws of the treoul net per hour)[Cassou-Leins *et al*., 2001]. Dauba (pers. com.) said that the treoul is used primarily in the lentic zone close to the banks.

A 'carrelet' net of 1 m^2 and mesh 10 mm and a nylon, monofilament, drift net of spider type, 25 m long, 2 m deep and 10 mm mesh size were also used as devices of capture (Cassou-Leins *et al*., 2001). Dauba (pers. com.) indicated that in 2001, attempts will be made to use a luminous juvenile trap.

At the laboratory, from each individual, the following information is taken: the overall length (LT) and the standard length (LS) in mm, the weight (P) to within 1 mg and the coefficient of condition K ($K = 100P/LS^3$ with P in g and LS in cm) [Cassou-Leins *et al*., 2001]. Daily coefficients of linear growth $Gl = [Ln(LT_{i+1}) - Ln(LT_i)]/t$ and weight ($Gp = [Ln(P_{i+1}) - Ln(P_i)]/t$ were calculated with T equal to the number of days between surveys *i* and *i+1* (Ricker, 1975).

Temperature, oxygen, conductivity and pH were recorded continuously; suspended matter, cations, anions, phosphorated and nitrogenized substances, and heavy metals, DBO5 and DCO were measured at the time of four water samples carried out over the period of study (from June to September) [Cassou-Leins *et al*., 2001].

1.3.5.3 Eastern Europe

Navodaru (pers. com.) evaluated the spawning success or year-class strength by measuring a Juvenile Abundance Index. In Ukraine the first summer abundance index of shad (spawned in the Danube) was measured using shoreline seine netting in the Black sea, to measure the number of fry per surface area fished. Navodaru used large stationary trap nets (7 mm knot to knot mesh size) installed on the shoreline in 5-10 m water depth.

The main problem with juvenile sampling in the Ukraine is an inability to differentiate between pontic shad, caspian shad (*Alosa caspia*) and black sea shad (*Alosa maeotica*), the fry of which share the same habitat for the first summer.

1.3.5.4 USA
Annual juvenile recruitment (appearance of juveniles in the ecosystem) of American shad, hickory shad, and river herring is measured in order to assess juvenile production, to predict future year-class strength, provide a signal for recruitment failure or major habitat changes, and assessment of hatchery-released larvae. Recruitment is measured by sampling current year juvenile fish abundance in producer areas (ASMFC, 1999). The sampling protocol (stations, sampling intensity and gear type) is consistent through time for the period for which the index is to be used.

The ASMFC Technical Committee annually examine trends in all required juvenile abundance index (JAI) surveys. If any JAI shows recruitment failure (ie, JAI is lower than 90 % of all other values in the dataset) for three consecutive years, then appropriate action is recommended to the Management Board.

1.3.6 Egg sampling

1.3.6.1 UK
The EA undertakes egg sampling at potential spawning sites in UK rivers known to support a twaite shad population, although this work does not constitute a routine survey. The location of spawning sites in the Rivers Teme (Severn), Wye, Usk, Tywi was investigated in 2000. Kick sampling was carried out at each site, to confirm the presence or absence of eggs. A standard macroinvertebrate hand net (250 m aperture) was used to collect material dislodged by kicking upstream of the net for 15 - 30 seconds. The net was checked for eggs after each kicking interval and any detritus or channel substrate removed before kicking resumed.

Shallow gravels were targeted for kick sampling, together with adjacent macrohabitat. If no eggs were found after a comprehensive assessment of the habitat was made, the survey was terminated (a comprehensive assessment of the habitat was judged by Caswell and Aprahamian (2000) to comprise approximately 25 kicks, or 30 - 40 minutes). If eggs were present, the extent of the spawning area was determined by progressively kick sampling (c. 10 m) upstream and downstream. To confirm the limit of a spawning area, sampling was continued for at least another interval after the last egg was recorded.

Plankton nets have also been used by the EA to survey for eggs (Aprahamian, pers. com.). A triangular frame supports the gape of the plankton nets, which are held on the river bed. The netting is carried out from a boat in deeper water than can be surveyed with kick-sampling methods. One person operates the boat and two handle the plankton nets.

Egg surveys are not suitable for quantitative assessments of shad stocks (Aprahamian, pers. com.). The problem with using egg surveys to quantitatively assess shad stocks is

that if fish have just spawned, many eggs will be sampled, whereas if spawning took place several days before, eggs will not be abundant, and this change in egg abundance does not reflect a change in shad stocks. Similarly, plankton netting could indicate completely different levels of egg abundance, depending whether netting is conducted by day or by night.

It may be possible to design a sampling programme that quantitatively measures egg densities (Aprahamian, pers. com.). However, to overcome variability in egg densities, both spatially (a site may by chance be directly where a fish has spawned) and temporally (environmental conditions, time of day and season may affect the density of eggs on a spawning site), sampling activity will need to include several sites per spawning site, and per river. These same sites will need to be measured throughout the spawning season to allow for changes in environmental conditions.

1.3.6.2 Other EU Countries

In France, shad eggs are collected with a Surber type net (like a kick-sampling net) or with a small trawl weighted on the bottom (a kind of trawl used in France to harvest scallops) [Dauba, pers. com.]. Egg surveys are not used as a quantitative estimate of shad stocks.

1.3.7 Electrofishing

Routine EA electrofishing surveys do not usually detect shad due to the location of the surveys near the middle and top of river catchments. Electrofishing surveys targeting juvenile salmonids are usually conducted too far up the catchment for shad to access. In recent investigations, CFB (Ireland) used electrical fishing during low-tide conditions and low water level in the R. Suir. A limited sampling effort was made on one occasion using two boats. The boats passed over a number of shallow gravelled areas and encountered a solitary shad. Given the shoaling nature of shad, the method would have immobilised or disturbed large numbers of shad, had they been present (CFB, 2000).

In the Garonne, France, Dauba (pers. com.) commented that electrofishing had been tested as a way of surveying for juvenile allis shad, but was found to be an unsuitable method.

1.3.8 Power station monitoring

UK

A large data set exists of 0-group twaite shad entrained on the intake screens of the Hinckley Point Power Station, in the Severn Estuary. Regular monthly sampling of fish (entrained on the cooling intake screens) has been undertaken at Hinckley B Power Station for 21 years (since 1980) [Henderson, pers. com.]. The monitoring at Hinckley is undertaken by PISCES Conservation Ltd. and supported by the Magnox Company (owners of Hinckley A- part of British Nuclear Fuels), Nuclear Electric (owners of Hinckley B) and the EA. Each party donates around £5000 per annum to support the work (Ferguson, pers. com.). The work at Hinckley B Power Station is ongoing. Environmental monitoring was undertaken at Oldbury Power Station from 22/05/96 until

17/03/99 by the Severn Estuary Research Group, based at the University of the West of England (Bird, pers. com.).

The monitoring of 0-group twaite shad at Hinckley B Power Stations is closely correlated to Aprahamian's study of adult shad (4+ year olds) caught in the estuary by netsmen. The data from the Hinckley Point B monitoring program can be used to calculate the statistical confidence in the interannual variation of shad abundance (Henderson, pers. com.).

Environmental monitoring is also undertaken at Stallingborough Power Station in the Humber Estuary. Hull Fisheries Institute was commissioned by the owners of the power station to research the extent of fish entrainment into the intake of the power station (Firth, pers. com.). Monitoring has been carried out since January 1999. In the first year three twenty-four hour surveys per month were made but from January 2000 until present sampling effort decreased to two surveys per month.

During 2000, 11 twaite shad were encountered at Stallingborough Power Station. Twaite shad are much commoner than allis in the Humber (Proctor, pers. com.). From January 1999 to January 2000, results showed that seven twaite shad were impinged in the first, third and fourth quarters, and one allis shad in the fourth quarter (Hyatt, pers. com.). A statistical model, taking into account environmental data from several power stations, predicted a total annual entrainment of 39 twaite shad (biomass 28.23 kg) and 7 allis shad (2.20 kg) at Stallingborough Power Station (Proctor, pers. com.).

Monitoring has been carried out at Hartlepool Power Station on the Tees Estuary since 1992 but shad are not detected on the intake screens (Peaty, pers. com.).

Blyth Power Station, North Yorkshire, has also begun sampling screen intakes (Peaty, pers. com.).

At King's North Power Station, Newcastle, Durham University has periodically undertaken monitoring of screen intakes (Peaty, pers. com.).

The EA possess a long time series of records for fish impingement monitoring at West Thurrock Power Station in the Thames Estuary (Richardson, pers. com.). Monitoring of fish entrained on the intake screens was carried out from the 1970s until 1997,when the power station was decommissioned (Colclough, pers. com.). Shad were detected in the trash samples at West Thurrock (Thomas, 1998). The position of West Thurrock Power Station meant that environmental monitoring detected more fish than stations further up the estuary (Colclough, pers. com.).

Monitoring takes place at Tilbury Power Station, on the Thames Estuary and it is scheduled to run for another five years (Colclough, pers. com.). Twaite shad have been recovered from the intake screens at Tilbury (Dutton, pers. com.).

There is a new power station at Barking, at the mouth of the River Roding. This has been

running for a year but a very sophisticated fish returning system makes it unlikely to be of use for monitoring shad in the Roding (Colclough, pers. com.). Inputs into the planning process now favour fine mesh around intake screens, to minimise fish mortality: new power stations are therefore unlikely to be of use when monitoring shad populations (Colclough, pers. com.).

Longannet Power Station in the Forth, Scotland, has been monitoring fish impingement intermittently for many years; this work restarted about 2 years ago (Elliot, pers. com.). However, shad are not found amongst the trash intake samples at Longannet (Hill, pers. com.).

In Northern Ireland, fish impingement monitoring has taken place since 1989 at four power stations; Coolkeeragh (Loch Foyle), Ballylumford (Larne Loch), Kilroot and Belfast West (Belfast Loch) [Moorhead, pers. com.]. The Northern Ireland Industrial Research and Technology Unit undertake the work on behalf of the Department of the Environment. For the first 5-6 years monitoring took place for a 24-hr period once per month. Sampling effort was reduced to a seven month period from October to April, because fish numbers dropped during the summer months and monitoring during these months was not cost-effective.

Monitoring at Northern Ireland power stations is supplemented by beam trawling at three locations; Bann River, Dundrum Bay and Carlingford Loch (Moorhead, pers. com.). Beam trawls have been carried out since 1993, in the spring and autumn, each year. Unfortunately, shad have not been detected, either at the power stations or in the beam trawls.

France
In the Garonne, attempts have been made to use juvenile allis shad impinged on the cooling intake passages at the turbines of the hydroelectric power stations as an indicator of year class strtength, but this sampling is considered difficult (Dauba, pers. com.).

1.3.9 Integrated approach to condition assessment

Monitoring of shad populations at specific sites in the UK is limited to the work carried out on the River Severn, by Dr Miran Aprahamian (EA) and Dr Peter Henderson (PISCES Conservation). Assessment of the adult spawning stock has been done using the catch data from commercial fishermen operating in the Severn Estuary. Recently, this data has not been available due to a reduction in the number of netting licenses issued. The condition of the Severn twaite shad population is now monitored by seine netting for juvenile shad in the autumn as they migrate seawards. Monitoring of juvenile shad entrained in the intake of Hinckley Point Power Station has been carried out since 1980, providing a unique data set for shad abundance in the UK.

In the Gironde-Garonne-Dordogne, France, three methods are used for monitoring allis shad stocks; fish passes, catch per unit effort of the commercial fishermen and counts of spawning fish on the spawning grounds (Chanseau *et al*., 2000).

On the Dordogne and the Garonne, the proportion of shad that spawn below hydroelectric works on each river is estimated (Tuilieres on the Dordogne and Golfech on the Garonne). Dauba (pers. com.) indicated that the difference in counts between fish passes on the Garonne (Toulouse and Golfech) gives the number of shad spawning between the two stations. These values are compared with the indices of use of the spawning grounds. Using a combination of the three abundance indicators (fish passes, commercial catch per unit effort and spawning site counts) it has been possible to make estimates of the total spawning stock on these rivers. Bellariva (pers. com.) suggested that these three indicators of abundance be used to estimate the size of the spawning population using a more or less empirical calculation.

Bellariva (pers. com.) commented that counts of adults at the spawning sites was a less precise method than the other two. Also, it is difficult to count all the spawning sites existing downstream from the fish passes at the control stations. When considered as a whole the counts made by the various methods provides a more or less precise estimate of stock every year. Provided the same methods are used each year, data is comparable between years.

On the Rhone, a number of methods have been used to monitor twaite shad (*Alosa fallax rhodanensis*) [Menella, pers. com.];

1. visual counts of shad passing the first lock
2. echo-sounding surveys for adults at the same lock
3. survey of shad catches by amateur and professional fishermen.
4. survey of shad on the spawning grounds.
5. power station entrainment survey of juvenile shad migrating downstream.
6. seine netting for juvenile shad as they migrate downstream.

Emphasis is placed upon Methods 3 and 4, which are the most effective (Menella, pers. com.). Method 1 is planned to commence next year. Method 2 has been largely abandoned because of problems in distinguishing shad from other species such as mullet.

1.3.10 Conclusion

A combination of two or three different monitoring methods seems to the approach of countries that monitor shad stocks. But these methods are different between countries ie France is the only country to count shad at spawning sites, USA calculates mortality and/or survival estimates. The methods most commonly used by each country are summarised below.

USA

- Annual spawning stock surveys and representative sampling for biol. data. (mark-recapture studies, enumeration at fish passes, CPUE)
- Calculation of mortality and/or survival estimates
- Juvenile Abundance Indices (JAIs)
- recreational catch and effort
- commercial fisheries catch and effort, samples

France

- Commercial and recreational catch data
- Fish counters (automatic video recording and processing of fish via viewing windows)
- Surveys on spawning grounds
- Juvenile surveys

UK

- Commercial catch (Severn)
- Power station monitoring (Severn)
- Juvenile surveys (Severn)
- (Kick-sample egg surveys to locate spawning grounds)

2. Current approaches to determining Favourable Conservation Status of shad across their range in the UK

2.1 Introduction

Conservation status is defined (in Article 1I of the EC Habitats Directive) for a species as "The sum of the influences acting on the species concerned that may affect the long term distribution and abundance of its population". Favourable conservation status (FCS) is defined as occurring when:

- "The population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats;
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future;
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis".

A method for determining the conservation status of shad in the UK is currently lacking. Work is being carried out in the Severn and Welsh rivers to monitor twaite shad populations, but where shad are detected elsewhere in the UK, data is not collected and used to monitor conservation status.

2.1.1 UK

2.1.1.1 Fishery-dependent monitoring

Fishery-dependent monitoring of shad in the UK is limited to the Severn Estuary. Even here, fishing effort has dwindled to such an extent that catch data from netsmen can no longer be used to produce an estimate of shad stock condition. Coastal catches of shad are not monitored, although trawlers and gill-netters operating around the UK have been observed to catch shad on a regular basis (eg Hillman, 2000). In summer months, shad are regularly caught as a bycatch of salmon and seatrout by river and estuary netsmen in the South-west. Recreational anglers on many rivers also catch shad. Presently, this data is not collected and used to determine FCS.

2.1.1.2 Fishery-independent monitoring programs

Numerous UK power stations commission monitoring of fish entrained on intake screens, and shad have been detected in some of these studies. Such ongoing studies could provide valuable data for determining FCS of shad in the UK. Fish counters in the UK are not suitable for monitoring shad for reasons discussed previously in 'favourable condition assessment'. With the exception of the Rivers Usk, Wye and Severn, shad detected by fish counters are present in such small numbers as to make video validation techniques impractical.

In the UK, the spawning distribution of shad is still unclear, which makes it difficult to

determine FCS. Evidence suggests that shad may be recolonising their former range as water quality improves in rivers such as the Thames; Colclough (pers. com.) has observed increasing numbers of shad in the Thames over the past few years. Estuarine and riverine surveys by the EA may detect evidence of shad presence, and possibly a spawning population, but this evidence is not used to determine FCS across the shad's range in the UK.

2.2 Other countries

2.2.1 France

In France monitoring of shad stocks is undertaken on a catchment basis, eg the Gironde-Garonne-Dordogne, Loire, Rhone etc. Approaches to stock assessment in different catchments are similar and estimates of stock size are produced. However, results from the various catchments supporting shad populations are not used to evaluate the conservation status of shad across its range in France. In other EU countries, the condition assessment of shad populations in specific rivers is not undertaken to the extent of the French, and consequently the conservation status of shad within those countries is not considered.

2.2.2 USA

The monitoring and management of shad populations in the USA is at an advanced stage. This is due, in no small part, to a well-structured management regime. The members of the Atlantic States Marine Fisheries Commission (Commission) recommended the preparation of a cooperative Interstate Fishery Management Plan (Plan) for American Shad and River Herrings. The Plan Review Team (PRT) continually monitors the status of the fishery and the resource, and reports on the status to the management board. The PRT consults with the technical committee, the Stock Assessment Subcommittee (SAS) and the relevant advisory panel, in making a review and report. The report will contain recommendations concerning proposed adaptive management revisions to the management program.

A state must submit its regulatory and management programs for shad and river herring to the management board for approval. Each state has a unique set of mandatory fishery dependent and independent monitoring programs for American shad, as well as recommended programs for hickory shad and river herring. Typically this will involve; annual spawning stock surveys and representative sampling for biological data; calculation of mortality and/or survival estimates; the recovery of any visibly marked animals; juvenile abundance survey.

The conservation status of American shad is monitored in great detail in each river system and the results are reported periodically to the commission. It is relatively easy for the Commission to identify favourable condition assessment in each river system, and therefore determine the conservation status of American shad across its' range in the USA.

2.3 Conclusion

In the UK, there is not a strategy in place for determining favourable conservation status of allis and twaite shad, across their range in the UK. Current monitoring, including commercial catch data, juvenile seine netting and power station fish entrainment studies in the Severn Estuary could be adapted to produce a means of determining FCS in shad. Ideally, similar studies in other parts of the UK (eg Thames and Humber and South-west rivers) will be established, so that data is available from more than one area of the UK.

Firstly, the distribution of shad across the UK needs clarification. This should be done by gathering spawning evidence, in the form of either eggs, juveniles or mature adults. Once the range is known, sites can be selected for routine monitoring to check that; the populations are viable; the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; the habitat is sufficiently large to maintain populations on a long-term basis.

In designing a monitoring program for assessment of favourable conservation status of shad in the UK, elements of the monitoring programs used in other countries should be considered. The methods used by France, namely counts of adults on the spawning site and viewing windows with automatic video observation of shad at fish passes, are proven to be effective in shad monitoring. Also, the well-organised monitoring regime used in the USA, is a good template to use when considering both favourable condition of shad in river systems, and FCS across the shad's range.

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