DETECTION OF FISH-FOOD PELLETS IN HIGHLY-CLUTTERED UNDERWATER IMAGES WITH VARIABLE ILLUMINATION

by

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Abstract

The focus of this research was to develop and test a method using image analysis to detect falling objects in a complex and variable underwater scene. This particular application involved the detection of fish-food pellets in netcage aquaculture systems. The problem was complicated due to the video camera positioning, number of other objects in the scene, and variable and uncontrollable background lighting conditions.

The image analysis program was developed and tested using images obtained from industry standard video cameras. Testing conditions were as follows:

- Food pellet diameter: 2 – 11 mm.
- Water visibility: 3.5 – 11 m.
- Fish size: 0.025 – 4.8 kg.
- Fish stocking density: 0.27 – 20.3 kg/m^3.

The resulting image analysis program consisted of novel image enhancement and object recognition algorithms and was combined with filtering methods to eliminate false detections. The program was capable of detecting food pellet events providing the following conditions were met:

1) The camera view area was positioned within the sinking path of the food pellets.
2) The camera was positioned with its lens pointed towards the water surface.
3) The camera lens and rigging were clear of debris.
4) At least three food pellets of area 30 pixels or greater were present in the sampled images for 8 consecutive seconds.

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1.0 Introduction

In 1999, the estimated worldwide production of farmed salmon was 785 000 tonnes and the British Columbia salmon farming industry was the fourth largest farmed salmon producer. Total production for B.C. in 1999 was 46 738 tonnes of dressed salmon, worth approximately $347 million (wholesale) and contributing 3 395 direct and indirect jobs to the economy. Farmed salmon is B.C.'s most valuable export crop (BC Salmon Farmers Association, 1999).

A typical salmon farm consists of 6 - 24 netcages (each 15 – 30 m on a side and 15 – 20 m deep), which are suspended in the water by floating walkways between them. A single cage would generally hold 20 000 to 50 000 fish. Major capital costs in salmon farming include netcages, walkways, feeders and a feed barge. Major operating costs include labour, feed, fuel and smolts (young, sea-ready salmonids).

Feeding costs are the single largest operating expense on a fish farm. Typically, feed accounts for 35 to 50% of a salmon farmer's operating budget (Drouin, 1998). Improper feeding increases production costs through feed loss to the environment and decreased fish growth (lower growth rates lengthen the time required to raise fish to market size, decreasing overall farm productivity and profitability). Waste feed can attract wild fish to farm sites increasing the risk of disease transmission and may cause poor water quality conditions in and around the farm sites if it accumulates and decays on the seafloor. Waste feed also increases the demand for the finite supplies of fishmeal (increasing the demand of feed relative to the supply), limiting the growth of aquaculture and raising the wholesale price of feed.

Feed is broadcast in a netcage by one of three methods: handfeeding, centralized feeding systems and decentralized feeding systems. Handfeeding is generally used for small fish in small cages. Centralized feeding systems consist of one or two large feed blowers in a central feed barge, with individual pipes going to each cage. Decentralized feeding systems consist of smaller, individual feeders at each cage.

Currently, the industry standard for controlling feed loss in Canada is to have an operator manually observe feeding with an underwater camera at a depth of 8 – 12 m, with the lens pointing towards the water surface. With an underwater camera, feed wastage can be controlled, as the operator can see when uneaten feed reaches the camera depth (if the camera view area is positioned within the sinking path of the food pellets). Feeding is stopped when the fish are satiated (very few fish appear to be eating) and food pellet loss occurs even at a low feed delivery rate. This method allows feeding to be tailored to the daily variations in fish appetite, resulting in decreased feed wastage and improved growth and feed conversion ratio (FCR - kg of feed per kg of fish produced) (Ang and Petrell, 1997). The main drawback to this method is that constant supervision by a farm worker is required to ensure that the camera is positioned properly (difficult under conditions of high current, fouled nets and stocking density > $5 kg/m^3$) and to monitor for pellet loss.

Automated commercial methods of controlling feeding are the Aquasmart and Akva feed sensors. The Aquasmart system uses a cone (1.5m diameter) suspended in the water column to direct uneaten pellets past an infrared photo sensor for counting. The Akva system uses a hydroacoustic detector suspended near the bottom of the cage and is set to detect a pulse of uneaten pellets. Another method to detect uneaten pellet is the airlift pump, in which the pump lifts uneaten pellets from the bottom of the netcage to the water surface, where farm workers may view the pellets.

An alternative method to detect uneaten food pellets consists of using video image analysis by a computer. In a previous project at the University of British Columbia, uneaten food pellets were detected using a downward pointing camera lens (Foster et al., 1993). In this configuration, the image segmentation process was straightforward because the background illumination is uniform (pellets appeared bright against a uniformly dark background). Drawbacks to a downward pointing camera lens are: (1) feeding behaviour cannot be observed by the operator and (2) the ambient light levels required for illumination are higher than for an upward pointing camera lens. The system developed by Foster et al. (1995) cannot be modified to work with an upward pointing camera lens because both a food pellet and its background have varying gray levels (there are 256 gray levels in an image with 255 as white and 0 as black). When a camera lens is pointed upwards, food pellets then appear dark against a varied background, which ranges from near white (the water surface) to black (fish and the cage sides).

For most industrial image processing systems, lighting, background and object placement are all carefully controlled to reduce image variability and ensure optimum contrast. Besides underwater images, varying backgrounds are also common in microscopic and medical imaging (e.g. Baldock and Graham, 2000; Keshavmurthy et al., 1999). The development of an object recognition system for detecting moving objects in images contaning varying backgrounds is not a trivial task. Underwater images are feature complicated and of poor quality due to the attenuation of light in water (the scattering of light causes edges to be poorly defined). Food pellet detection is made more difficult because the apparent shape, size and intensity of food pellets vary as they tumble through the water column. Also, in netcages, a large number of non-pellet objects including fish, waste matter, netting, algae, marine organisms and the camera cable are typically present. Lighting conditions vary with season, time of day and weather conditions. Water quality, fish size and stocking densities also vary dramatically.

An automatic uneaten-pellet detection system for an upward pointing camera lens offers several advantages over existing systems. It could allow a single operator to feed multiple cages simultaneously, reducing time and labour costs associated with feeding as a computer system can be used to monitor multiple cages. The operator is provided with direct evidence of workability, as images containing detected pellets can be saved and made available for inspection. The operator can then view the video images to ensure that feed placement is correct and can base feed management decisions on the observed feeding activity and pellet detection data.

2.0 Objectives

The overall objective of this research was to develop and test computer algorithms that could be used to detect and discriminate uneaten fish food pellets from non-pellet objects in underwater video images that had been captured using an upward pointing camera lens.

Specific sub-objectives were to:

a) Determine the accuracy of the resulting pellet recognition software under various fish stocking and environmental conditions.
b) Develop practical applications for the resulting pellet recognition algorithm.
c) Determine the maximum number of cameras that can be simultaneously monitored using the existing software in a single computer system.

An ideal system will:

1) Have no false pellet detection alarms.
2) Work under all fish stocking, pellet size and environmental conditions.
3) Require no specialized cameras.
4) Have little or no need for calibration.

3.0 Literature Review

The following sections contain a review of literature relevant to designing an automated, vision based, fish food pellet detection device.

3.1 Overview of Farmed Atlantic Salmon Feeding Behaviour and Practices

The feeding behaviour of farmed salmon, how to determine the amount of feed to supply and estimate satiation, and how to monitor the feeding event to prevent the loss of fish feed will be discussed.

3.1.1 Feeding behaviour of farmed Atlantic salmon

Salmon in general are considered to be primarily visual feeders (Guthrie and Muntz, 1993), although for wild fish, odour also plays an important role. In a salmon farming situation, odour is of negligible use for food capture. Due to the high density of food in the water, its odour spreads throughout the enclosure, making the identification of individual food particles by their odour nearly impossible. When prey is taken into the mouth, taste and texture are used to determine whether to ingest or expel the prey object. In general, studies have shown that salmon have difficulty identifying and capturing food pellets at dusk or when water visibility drops below three metres (Ang and Petrell, 1998). Although salmon are visual feeders, they tend to feed lower in the water column under bright lighting conditions (Petrell and Ang, 2001).

Farmed salmon tend to form two general structures within a netcage depending on feeding activity. When the salmon are not feeding, they will circulate around the outer perimeter and near the bottom of the netcage, leaving a large area in the cage centre and top devoid of fish (Ang and Petrell, 1998). Occasionally, when currents are strong, the fish will tend to orient themselves into the current and hold their position instead of circulating around the cage. During a feeding event, the fish tend to aggregate in the area where food pellets are present and individuals actively forage for food using an s-shaped foraging pattern (Ang and Petrell, 1998). As the numbers of feeding fish decline and uneaten food pellets become readily available, feeding salmon begin to follow the pellets downwards instead of allowing the feed pellets to pass by them.

Observations of the size distribution of farmed salmon in a netcage before feeding and when the fish are hungry show that the larger fish can collect near the water surface while smaller fish are closer to the cage bottom (Boucher and Petrell, 2000; Shieh and Petrell, 1998). The largest salmon in a farmed population tend to be the most dominant as the greatest access to food generally allows for higher growth (Kadri et al., 1996). Competition is an important factor when deciding how to feed farmed salmon and should be minimized.

3.1.2 Feeding studies – how different feed regimes affect growth and FCR

In general, most feeding studies to date have focused more on juvenile salmon and small enclosures such as tanks or experimental netcages. In many cases, it is unclear exactly how these small-scale studies extrapolate to commercial farming operations with adult salmon in large netcages at higher stocking densities. A careful examination of the small-scale studies does provide some insight into what an acceptable feeding regime may be.

A study of three feeding methods of adult (1.1 – 1.2 kg) rainbow trout (*Oncorhynchus mykiss*) in six 144 m^3 netcages (Alanara, 1992) showed how feeding regimes can affect growth and feed conversion due to fish behaviour. The three feeding regimes used were: time restricted feeding, restricted demand feeding and unrestricted demand feeding. Demand was assessed by the frequency of bites on a small rubber knob at the end of a pendulum. Time restricted feeding used a preset ration, delivered in small quantities throughout the day by a preset timer. Restricted demand feeding provided food on demand up to a maximum preset amount every day. Unrestricted demand feeding released a small quantity of feed based on the bite frequency on the trigger. Results showed that restricted demand feeding produced an FCR of 1.1 (kg feed per kg of fish growth), while unrestricted demand feeding produced an FCR of 1.6. Growth was highest in the unrestricted demand-feeding group and lowest in the time restricted feeding group. No statistical analysis was completed on the growth or FCR data but the author suggested that providing a restricted ration in short, regular feeding intervals induces stress and high competition for food, resulting in higher energy demand while unrestricted feeding results in excessive feed intake and a higher FCR.

The general purpose of the feeding system on a salmon farm is to deliver feed in such a way as to maximize the profitability of the salmon farm. To feed fish in a way that maximizes growth rate and minimizes FCR, feed must be provided in a way that matches their nutritional needs as well as the physiological and behavioural mechanisms that control their feeding behaviour while minimizing feed wastage.

The most effective way to reduce competition is to feed at the highest possible rate and spread the food pellets over the largest possible volume to give all salmon in the population the greatest possible opportunity to feed (Thorpe et al., 1990).

Several studies have been undertaken to determine the optimal rate and duration for feeding. In general, it has been found that feeding at a slow rate over long periods of time does not increase overall population growth (Jorgensen and Jobling, 1992), but rather increases feed conversion ratios (Alanara, 1992). This may result from the ability of dominant fish to monopolize the food supply and overeat when the density of feed particles in the water is low.

It is well-known that appetite is not simply a function of temperature and fish size but follows complex daily, seasonal and developmental appetite rhythms (Metcalfe, 1994). Stresses such as the presence of predators (Ang and Petrell, 1998; Blyth et al., 1993) or disease (Bjorklund et al., 1990) may also have a negative impact on fish appetite. Several studies (Ang and Petrell, 1997; Blyth et al., 1993; Juell et al., 1992) have shown that a preset ration based on feeding tables is not sufficient to adjust for day-to-day fluctuations in appetite; rather it is necessary to provide some form of feedback control system for feeding. Careful monitoring of feed consumption is especially important near the end of the growth cycle, as this is when the farmed salmon consume the largest amount of feed.

Currently, there is no objective way to know exactly when feeding should cease (although there has been a large amount of work done on the related problem of determining when the fish are satiated). As a general practical rule, satiation is defined as the point at which uncontrolled pellet loss occurs (Ang and Petrell, 1997).

It is important to feed in such a way as to minimize preferential access to food, so that growth rates across the fish population are equal and body size is nearly uniform. To decrease inter-individual competition, it is important to feed at the highest rate possible and distribute the food as evenly as possible throughout the cage volume. At the same time, the feed discharge rate should not exceed the over-all consumption rate so that pellet loss does not occur. Also, feeding must continue for a sufficient length of time to ensure that all fish in a cage have a sufficient length of time to feed.

3.1.3 Methods for controlling feed delivery

The traditional method of controlling feed delivery and gauging feeding activity was to use a combination of the ration method and visual observation of surface feeding activity. The ration method involved dispensing a predetermined food ration based on fish size, time of year and water temperature. Using surface feeding activity, a farm worker bases feed delivery on the amount of feeding activity observed at or near the water surface. Long-term feeding studies have shown that these methods perform poorly in terms of estimating the daily appetite of farmed salmon (Ang and Petrell, 1997).

The most widely used method of monitoring feeding at the present time is to use an underwater (monochrome) video camera, connected to a video monitor near the cage. Colour video cameras are not used as most colours are rapidly absorbed within a few metres of the water surface. The farm worker observes the monitor for feed distribution and pellet loss during feeding. This method has been shown to improve feed conversion and fish growth while reducing feed wastage as the feed rate is better matched to fish appetite than by traditional methods such as surface behaviour or ration feeding (Ang and Petrell, 1997).

As previously mentioned in the introduction, automated methods of controlling feed delivery include: the air-lift pump, the Aquasmart pellet detector (which uses an infrared sensor suspended at the base of a cone) and the Akva pellet detector (which uses a hydroacoustic sensor).

3.2 Image Analysis

The following sections will describe the properties of underwater video images and the general principles for their processing and analysis.

3.2.1 Image formation and description

Underwater images are very different from most images taken in the terrestrial environment. In fact, due to the high degree of scattering, imaging underwater can be considered similar to imaging through fog (Palowitch and Jaffe, 1991). The transmission of light through water can be affected by three different factors: absorption due to pigmented species in the water column, diffraction by particles whose dimensions are the same order as the wavelength of light and refraction by larger particles with an index of refraction that differs from water. Collectively, these terms are grouped together into one term called the attenuation coefficient. The total attenuation coefficient is a decay constant that indicates the removal of light intensity per unit distance in a water sample (Palowitch and Jaffe, 1991). Equation 1 relates the light intensity (I) at a depth from the water surface (d) to the attenuation coefficient (λ) and light intensity at the water surface (I(0)).

Equation (1) $\mathbf{I(d) = I(0) * EXP(-\lambda * d)}$

From Equation (1), it can be seen that the intensity of light falls off exponentially with depth in the water column. As previously mentioned, the scattering of light in water makes imaging in water similar to imaging through a fog. The resulting images appear "fuzzy", lacking in contrast (the difference in intensity between an object and its background) and edge definition.

A general description of underwater video images taken in a netcage is as follows. With an upward pointing camera lens, objects in the water column appear dark against a brighter background, which is the water surface. Depending on cage size, the net may make up a portion of the image and creates a dark background near the image edges. As a result of light attenuation and backscattering, the colour of objects varies from near white at the water surface to black near the camera lens. When the seawater is very turbid, surface light intensity is low, fish stocking density is high or the camera is deep, little light reaches the camera, backscattering is extensive and the images have little contrast or edge definition. When the water is clear, the images tend to have a much higher level of contrast. The actual pellets themselves range in apparent size and intensity depending on their depth in the water column. The food pellets may appear against a background of the water surface, foraging fish, or the cage sides. As well, food pellets may be partially occluded by underwater objects.

Camera and lens selection also plays a critical role in image quality. A high quality camera with good light compensating features is capable of functioning under very high and low lighting conditions without loss of image quality. An interlaced camera produces blurred images when capturing a scene with rapidly moving objects. High quality lenses and dome ports reduce image distortion and increase light gathering abilities, producing a more resolved underwater image. Digital cameras were not considered as they tend to be expensive, are not used in salmon farming and do not yet have the image forming capabilities of analog cameras.

3.2.2 Preprocessing

The purpose of preprocessing is to correct defects and enhance certain features of the acquired images. In some cases, the surroundings can be manipulated through image placement and lighting so that the acquired image is easier to process. This approach is impractical for aquaculture applications where it is generally not practical to manipulate lighting or background (Foster, 1993). Typical image defects may include non-uniform illumination as well as random and systematic noise. All processing steps remove some information from the image, but are considered acceptable as long as desirable information is enhanced and undesirable information is suppressed.

Non-uniform illumination can be corrected through the use of a background equalization operation where the background intensity of an image is measured at several points and an image of the measured background is produced. The background image is then subtracted from the original image to produce a new image with a uniform background (Keshavmurthy et al., 1999; Baldock and Graham, 2000). This operation makes it much easier to separate objects from the image background, as only a single threshold (Section 3.2.3) is then required to segment the entire image.

Random noise can be removed from an image in several ways. The simplest method of removing random noise is to acquire multiple images of the same scene over an extended period of time and average them. Random noise will tend to cancel itself out while the desired signal will accumulate (Baldock and Graham, 2000). The main drawback with this method is that it is not useful for dynamic scenes where the image is always changing and is therefore, unsuitable for fish farming applications where fish and food pellets are constantly in motion.

Other methods of random noise removal involve the use of averaging filters, which average the pixels in a given neighborhood, and rank filters (Baldock and Graham, 2000). The simplest averaging filter sets each pixel to a value equal to the average of the pixels in a 3 by 3 neighborhood. The main drawback to this filter is that it tends to blur edges and fine details. One way to reduce blurring is to assign weights to different pixels in the neighborhood and allow more emphasis to be placed on the most central pixels (Ko and

Lee, 1991; Patton and Tempst, 1993). Another method of noise removal is to use a rank filter, such as the median filter, which ranks the pixel values in a given neighborhood and assigns the median value to the central pixel. A median filter tends to cause less blurring of edges than an ordinary averaging filter and additional emphasis can be placed on the central pixels to further reduce blurring, if desired.

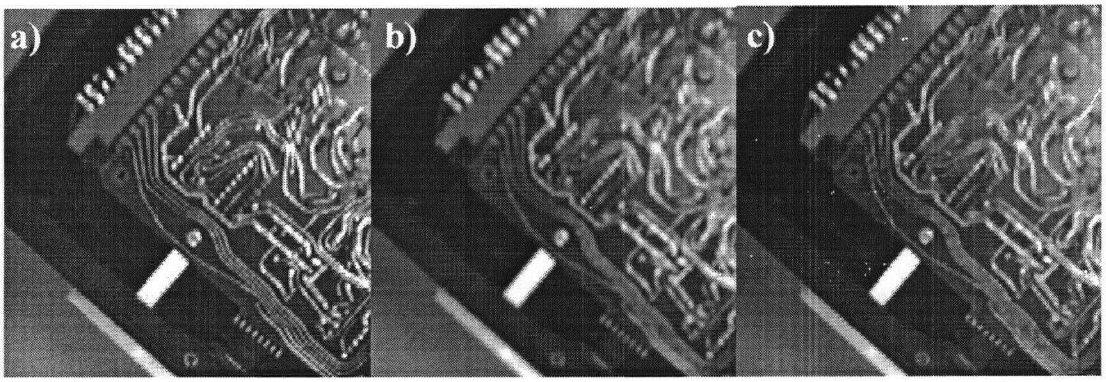


Figure 1: a) original image showing all details, b) averaging operation on original image, c) median filter on original image.

When it is necessary to remove systematic noise in an image, the noise portion of the video data can be modeled and removed from the image by subtraction. One example is to use the Fourier transform, where image data is converted into a frequency domain. Noise is then removed by subtracting those frequencies that correspond to the noise signal. Afterwards, the image is transformed back into pixel values (Baldock and Graham, 2000).

3.2.3 Object detection

In short, object detection is performed by segmenting an image to separate the image background from the objects of interest. The simplest form of image segmentation is thresholding, where an image is binarized by specifying a pixel intensity level above which all pixels are converted to a value of 1 (white) and all pixels below are converted to a value of 0 (black). The intensity level to segment at can be arbitrarily set, or can be set by looking at a histogram of the image and choosing a level that lies between the background intensity and the object intensity (Baldock and Graham, 2000). Another method of object separation is edge detection. In this case, a series of pixels with high intensity gradients (gradients in one or more directions may be detected depending on the edge detection method used) are converted to one intensity value and pixels with low gradients are converted to another intensity value. The resulting image contains an outline of all the objects in the image (Baldock and Graham, 2000). A third method of object separation is called watershed separation. The watershed algorithm starts with a high threshold value that only detects a portion of each object in the image. The threshold is then lowered one gray level at a time until each of the object boundaries touch; however, none of the objects are allowed to merge (Baldock and Graham, 2000; Brandtburg and Walter, 1998). Watershed techniques are a useful method for object counting, but tend to be a poor choice when detailed measurements or object classification must be completed.

3.3.4 Object classification

After objects in an image are separated from the background, the next step is to classify them based on their features. Ideally, the features used for classification should have the greatest possible differences between the different classes to ensure the most reliable classification possible. Typical features that are used for classification include shape, size, colour and texture (Baldock and Graham, 2000). After the object features are measured, classification can proceed in three general directions: the use of a set range of values, between which the given features of an object must fall to belong to a certain class, the use of a statistical method such as Bayes' formula where objects are classified based on the probability that their given features are common to objects of a certain class and finally, the use of an artificial neural network (ANN) where all measured features are input to an ANN and the object classification is the output (Baldock and Graham, 2000).

3.3 Summary of Prior Art

The following sections will present and discuss an imaging system designed to detect and count uneaten food pellets in a sea cage developed at U.B.C. (Foster et al., 1995).

3.3.1 System layout

The overall imaging system consisted of a light-compensating camera, suspended in a netcage with its lens pointing downwards. The camera was connected to an S-VHS VCR and video monitor to record pellet loss during a feeding event. After the feeding event was recorded, a computer was used to grab and process the video images frame-by-frame to extract and count uneaten food pellets. With a downward pointing camera, food pellets and fish appeared white against a dark background (the cage bottom).

3.3.2 Preprocessing and object detection

Since the image background was dark gray and the food pellets appeared nearly white, an automated thresholding system was used to detect the food pellets, with the threshold gray level set three standard deviations above the mean background gray level. After thresholding, dilation and erosion operations were performed to smooth the edges of the objects and to remove noise from the image. In simple terms, an erosion operation removes pixels from the edge of each object while a dilation operation adds pixels.

3.3.3 Object classification, tracking and counting

As a large number of pellets were found to be overlapping in the images, object separation was performed as a first step. Objects were divided at points of edge interactions, to separate overlapping food pellets. After separation, object features were measured so that classification could be undertaken. The features measured were:

Equation (2) $\textbf{circularity} = \textbf{perimeter}^2 / (4 * \pi * \textbf{area})$

Equation (3) **bounding area ratio = object area / bounding box area**

Equation (4) **minor to major axis ratio =
length of minor axis / length of major axis**

Equation (5) **minimum to maximum radius ratio =
minimum radius of object / maximum radius of object**

To generate the classification function, the four feature values were calculated for a set of food pellets. Class mean values and the covariance matrix were calculated for each feature. Objects were then classified based on the following distance function:

Equation (6) $\mathbf{D(x,m) = [(x-m)^T S^{-1}(x-m)]^{0.5}}$

Where x is the feature vector for the object to be classified, m is the class mean feature vector, S is the covariance matrix for the four features and T represents the transpose operator. In Equation (6) D represents the distance of a given object's features from the mean value for objects of a given class (in this case, food pellets). For this application, the maximum value of D (for an object to be classified as a food pellet) was set such that 97% of the detectable pellets were classified as food pellets.

As one of the objectives of this project was to be able to accurately count the number of food pellets passing the camera, an object tracking and counting algorithm was developed. Objects were tracked from frame to frame by overlaying the detected objects and matching those that were detected in consecutive frames. This prevented the possibility that the same object would be counted more than once.

3.3.4 Results

The average accuracy of the counting algorithms (based on consecutive images acquired at a the standard video rate of 30 frames per second) was found to be ±10%. One of the main problems with this system was that the processing speed was too slow for it to be implemented in real time. Another problem with the system was that light tended to be blocked by the feeding fish, greatly reducing the illumination so that it was difficult to detect the food pellets. It was suggested that an underwater light source be attached to the camera or a higher quality camera that is more sensitive to light be used.

4.0 Materials and Methods

A methodology for food pellet recognition in a netcage using an upward pointing camera lens was developed following a literature review of existing methods. Details of the site characteristics used for development and testing, materials used and methods for algorithm development, testing and validation are detailed in the following sections.

4.1 Site Characteristics

A variety of salmon farming conditions were examined to develop and test the pellet recognition algorithms. During initial testing, video tapes (S-VHS format) of previously recorded feeding events were used.

Additional videotapes of feeding events were collected during site visits to salmon farms. The characteristics of the sites used for algorithm development and testing are as listed in Table 1. At different sites, different feeding methods were used (depending on the farm management). The fish were fed either continuously by machine (continuous feeding), nearly continuously (5 s or more between pulses of feed) by machine (burst feeding) or by hand (handfeeding).

A food pellet is cylindrical in shape with a length to diameter ratio of 1.5:1. Food pellets are described in terms of their diameter.

Table 1: Site characteristics of video footage used for algorithm testing and development.

Date	Number of Cages	Cage Size LxWxD (m)	Pellet Size (mm)	Fish Size (kg)	Stocking Density (kg/m^3)	Water Visibility (m)[1]	Camera Depth (m)
July 94	1	15x15x15	9	4.3	5.6	4	8-12
Oct 94	1	15x15x15	9	2.1	6.8	8	8-12
Aug 97	2	12x12x15	8.5	2.75	10.5	3.5-8.0	8-12
Aug 97	2	12x12x15	6.5-8.5	2.3	6.8	3.5-8.0	8-12
June 00	2	23x23x20	9	3.8	11.0	4-5	12-20
June 00	1	23x23x20	9	2.8	11.1	4-5	12-20
June 00	2	23x23x20	9	4.0	12.1	4-5	12-20
June 00	1	23x23x20	9	4.8	17.0	4-5	12-20
June 01	2	25x25x15	11	4.6	23.1	10-10.5	4.5,11
June 01	2	25x25x15	11	3.9	20.0	10-10.5	4.5,11
June 01	1	25x25x15	11	4.4	25.4	10-10.5	4.5,11
June 01	1	25x25x15	11	5.2	18.2	10-10.5	4.5,11
July 01	2	31x31x18	8.5	2.9	5.6	5.0	4.5,14
July 01	1	31x31x18	8.5	2.4	4.8	5.0	4.5,14
July 01	3	31x31x18	6.5	1.0	2.5	5.5	4.5,14
July 01	1	12x12x15	2.0	0.025	0.27	5.5	4.5,14

[1] Measured using a Secchi disk at 2:00 PM. The Secchi disk reading for water visibility uses a circular disk divided into four quarters: two black and two white. To take a reading, the disk is lowered into the water to the point at which it is just visible to the human eye and that depth is recorded as the water visibility.

4.2 Materials

All images were obtained from non-interlaced cameras. The brand of camera and type of lens varied from site to site depending on the farm management. The images were recorded on S-VHS videotapes using a Panasonic AG-1980 or a Panasonic AG-1960 VCR. During analysis in the lab, images were displayed using either a JVC BR-S822U editing deck or a Panasonic AG 1980 VCR. Images were digitized using a standard monochrome frame grabber. The pellet recognition algorithm was run on a 0.95 GHz Pentium III computer, using both standard imaging software and customized imaging algorithms. Computer code was developed and tested using spreadsheet analysis, numerical techniques and prototyping software. Final programming of the pellet detection program was carried out by a staff programmer in the Chemical and Biological Engineering Department at UBC.

4.3 Algorithm Development

As previously mentioned, there are three steps in the pellet recognition algorithm: preprocessing, object detection and object classification. In actual application, there is one additional step, alarm triggering. In the triggering step, the pellet detection data is analyzed to determine the point at which an alarm should be triggered to indicate uneaten food pellets. The following sections will detail the development and testing of the pellet recognition algorithm at each of these steps. Results of the effectiveness of the preprocessing steps will be included in this section. All other results will be presented in the Results section.

4.3.1 Preprocessing

A software-controlled video gain adjustment on the frame grabber was used to ensure that the optimum image brightness for pellet detection was achieved. The gain setting controls the voltage of the video signal to which each pixel gray level is assigned. If the gain setting is too high, the image will appear bright and detail in the brightest areas of the images will be lost. If the gain setting is too low, the image will appear darker and detail in the darker parts of the image is lost. The frame grabber had a default gain adjustment algorithm; however, it was found to be unsuitable, as it tended to "wash out" some of the pellets (Figure 2). Another gain adjustment algorithm was developed using software to meet the following objectives:

1) Minimize the food pellet and fish intensity values.

2) Maximize the overall image contrast for the human observer.

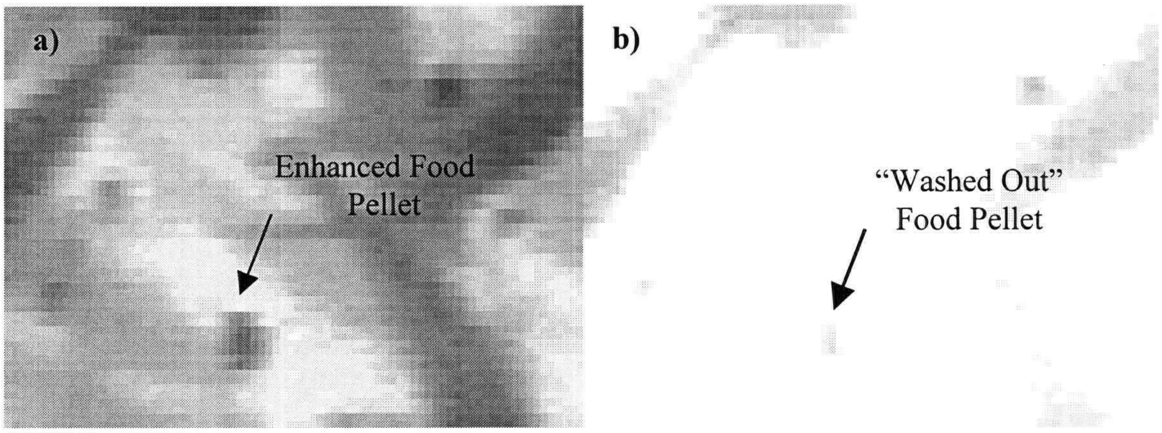


Figure 2: Comparison of an image grabbed with (a) and without (b) gain optimized.

The steps of the new gain adjustment algorithm are as follows:

1) Determine the maximum pixel intensity (I_i) in the current image (P_i)

2) If $I_i > I_{max}$, the maximum allowable image intensity, then decrease the gain by one step value, G_{Step}.

3) If $I_i < I_{min}$, the minimum allowable image intensity, then increase the gain by one step value, G_{Step}.

4) Digitize the next image (P_{i+1}) using the adjusted gain setting.

I_{max}, I_{min}, and G_{Step} were determined by experimentation using images from a range of lighting conditions. I_{max} and I_{min} define the tolerance around the target maximum pixel intensity (I_i).

Several image enhancement filters were tested on sample pellet images to determine which one was best at enhancing the detectability of the food pellets and reducing the detectability of non-pellet objects, while using as little computer processing power as possible. Some of the image enhancement filters that were tested included: average, median, sharpening, erosion and dilation, edge enhancement, and de-interlacing. Smoothing filters such as averaging and median removed noise from the image, but tended to blur the pellets too much and obscure some of the smaller pellets.

Use of a sharpening filter enhanced noise in the image, making pellets difficult to detect. The use of grayscale erosion and dilation removed object features, making it difficult to discern between pellet and non-pellet objects. Edge enhancement worked well, but made detection of pellets difficult if they were located near another edge such as a fish. Figure 3 (a-h) shows the effects of the different enhancement algorithms on a sample image containing a food pellet. Results indicated that a customized de-interlacing algorithm developed by Dr. Petrell was most effective at enhancing pellet-like objects because it reduced image blur caused by object movement.

Another result of the de-interlacing algorithm is that two distinct images separated in time by $1/60^{th}$ of second can be produced, one based on the odd video field and one based on the even field. Detection can then be carried out on either the odd, even, or both fields. This feature turned out to be valuable for pellet detection (see Results).

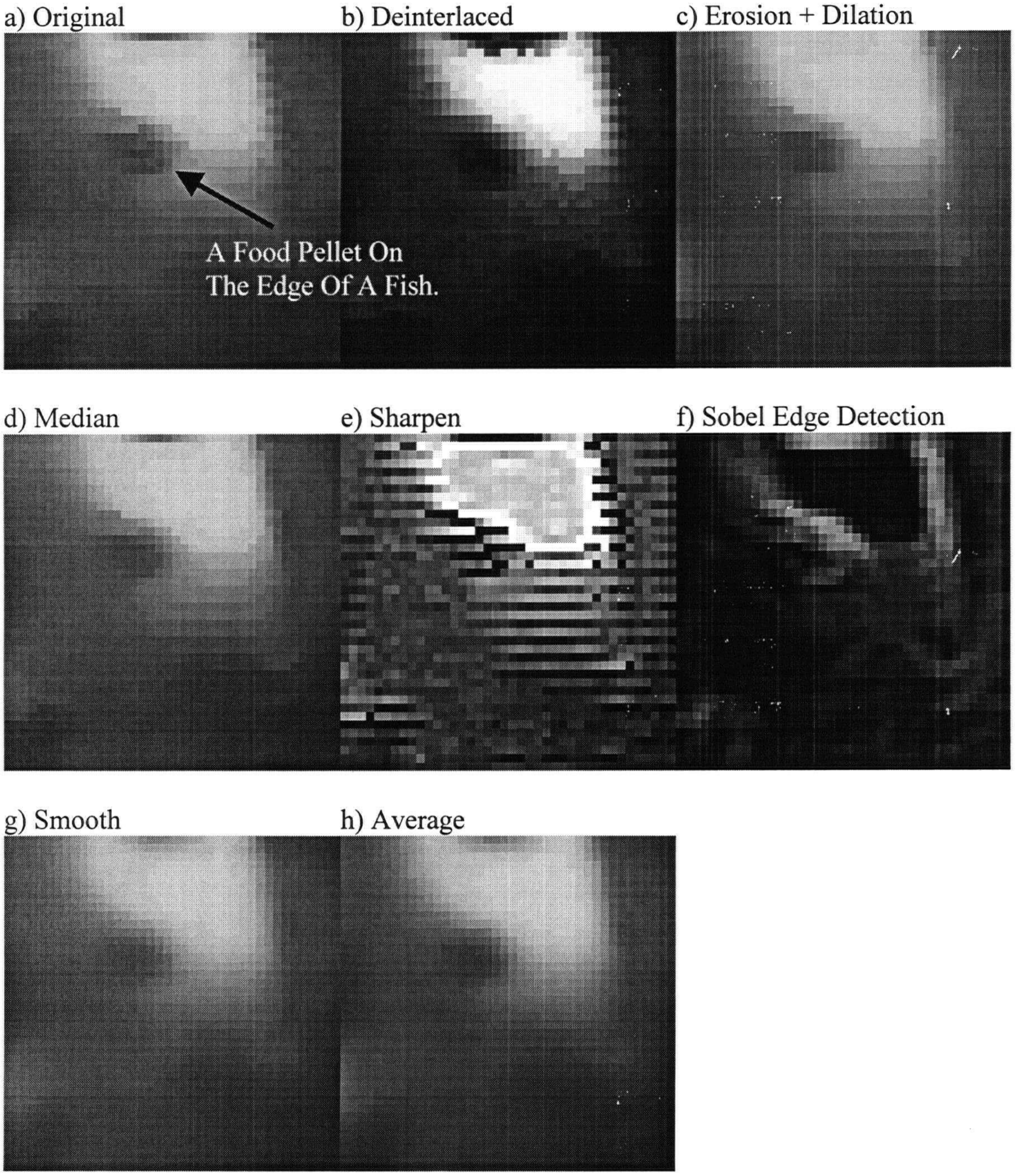


Figure 3: (a-h) Effect of various filters on final image quality.

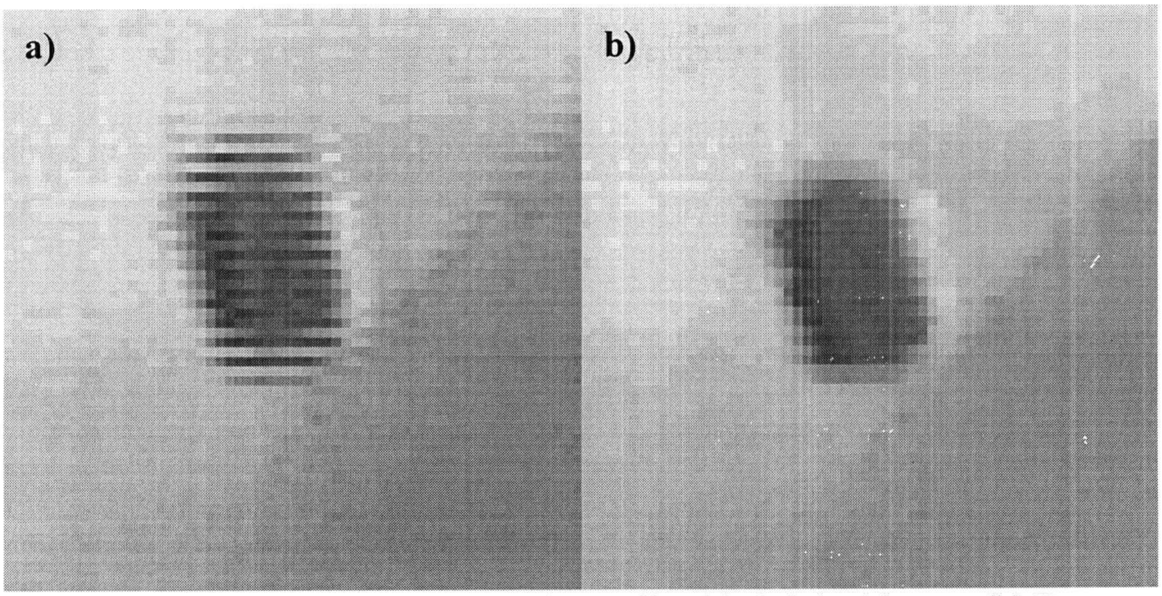


Figure 4: Comparison of a fast-moving pellet (a) Original image (b) De-interlaced image.

4.3.3 Object detection

Multiple thresholding (Section 3.2.3) was used to separate pellet objects from the image background. More complex methods of object separation such as background equalization or watershed separation were found to be of little benefit to separate and identify the food pellets. Multiple thresholding is simply a variation of normal thresholding, where the image is binarized at several intensity levels instead of just one because there is uncertainty as to the intensity of objects relative to the background. For example, in the same pellet image it was possible to have bright pellets against a bright background, dark pellets against a dark or bright background and anything in between.

The steps of the object detection algorithm are as follows:

1) I (threshold intensity) equal to I_{MIN} (a preset minimum intensity value).

2) Consider all pixels with intensity > I as background and all pixels with intensity $\leq$ I as objects.

3) Perform object classification (Section 4.3.4) to identify and count food pellets.

4) Increase I by a preset threshold step value, I_{STEP}, and repeat steps 1 – 3. Stop when $I \geq I_{MAX}$ (a preset maximum intensity value).

5) Pool all of the counted food pellets, eliminating duplicate pellets by comparing the centroids of all detected pellets by the following method: if the coordinates of the centroid of a detected pellet is within 5 pixels of the centroid of another pellet, eliminate the pellet with the smallest area.

I_{MIN}, I_{MAX} and I_{STEP} were determined by experimentation using images from a range of lighting conditions (for more details on I_{STEP}, see Results).

If the objects to be detected were darker than the image background, I_{MIN} was set slightly lower than the minimum background intensity and I_{MAX} was set at the maximum object intensity.

4.3.4 Object classification

Several methods were used to classify pellet and non-pellet objects. Various features of pellet and non-pellet objects were examined to determine which classification features could be useful to discriminate food pellets. Features included standard descriptors used in imaging (measured area (A), roughness (R), compactness (C) and elongation (E)) as well as three new features, which were developed based on the specific properties of underwater food pellet images. The new parameters tested were: relative contrast, sinking speed and expected intensity. The standard feature descriptors were calculated as follows:

Equation (7) $\mathbf{A = \sum_{i=1}^{n} pixel_i}$

where :

A = area, the sum of pixels in an object

Equation (8) $\mathbf{R = P / P_C}$

where :

P_c = convex perimeter

P = perimeter

Equation (9) $\mathbf{E = L / B}$

where :

L = length

B = breadth

Equation (10) $\mathbf{C = P^2 / (4\pi A)}$

where :

P = perimeter

A = area

The relative contrast measure was developed based on the observation that pellet objects of the same shape and size as non-pellet objects tended to have a greater variation in gray level intensity than non-pellet objects. In other words, the difference between the maximum and minimum intensities within a food pellet was greater than the difference in maximum and minimum intensities within a non-food pellet. The difference in contrast within an object was measured by multiplying the difference between the maximum and minimum object intensities by the mean object intensity and was termed the object contrast (OC). The object contrast measure was found to vary, depending on the contrast of the entire video frame (in dark background images, the theoretical object contrast was reduced relative to bright background images). To adjust for variations in the contrast of video frames (FC), Equation 11 (termed the relative contrast) was developed using linear regression (Minitab statistical software) with a sample size of 200 food pellets and 116 non-pellet objects.

Equation (11) $\mathbf{RC = (OC - A * FC)/B + C}$

where :

$\mathbf{RC}$ **= relative contrast**

$\mathbf{OC = (I_{MAX} - I_{MIN})I_{MEAN}}$

$\mathbf{FC}$ **= the intensity difference between the 99% and 1% pixels in an image**

$\mathbf{A, B, C}$ **= regression constants**

In an image where food pellets fall toward the camera, the measured area of a pellet will increase in a predictable manner. Objects such as waste matter and algae are nearly neutrally buoyant with settling velocities ranging from 0.01 – 4.0 cm/s (Wong and Piedrahita, 2000), while the average settling speed for large diameter food pellets is 12.7 cm/s (Petrell and Ang, 2001). Non-pellet objects should have little to no area change when viewed in consecutive images. To examine sinking speeds, 400 pellets and 400 non-pellet objects were tracked frame by frame. The sinking speed equation was as follows (frame rate = 1/30 s):

$$\textbf{Equation (12)} \quad S = (A_2 - A_1)/A_1$$

where :

S = **Sinking speed**

A_1 = **Object area in image frame i**

A_2 = **Object area in image frame i + 1**

Expected intensity was developed based on the theory of light scattering and absorption in water (Section 3.2.1). Based on light attenuation in water and backscattering, a pellet that is further away from the camera should have a higher intensity (be lighter in colour) than a pellet that is closer to the camera. As a result, smaller pellets appear lighter due to their greater distance from the camera, and larger pellets appear darker due to their smaller distance from the camera. In theory, the ideal relationship between measured area and intensity has a similar form to Equation 1, Section 3.2.1. An equation to determine the expected intensity of a food pellet was developed (along the lines of Equation 1) using regression (Minitab statistical software) with a sample size of 216 randomly selected food pellets and 116 non-pellet objects.

$$\textbf{Equation (13)} \quad I_E = K * EXP(-A/M)$$

where :

I_E = **Expected intensity**

A = **Object Measured Area**

K, M = **Regression Constants**

The resulting between actual intensity and expected intensity (Equation 13) for an object of a given measured area was then used to separate pellet and non-pellet objects.

4.3.5 Feature selection

To examine classification in terms of object features, the following process was used. First, large samples of 274 to 1000 images of pellet and non-pellet objects were measured to determine whether or not separation was achieved and to determine the feasibility of measuring the given feature. If a feature could not be accurately and reliably measured or there was no reasonable amount of difference in the feature between pellet and non-pellet objects, the feature was discarded. Measured area, elongation, roughness, compactness, relative contrast and expected intensity were compared to each other by measuring their degree of correlation (using Minitab statistical software). Any time two features were found to be correlated $p < 0.05$, one was eliminated from the final classification algorithm. When eliminating one of two closely related parameters, the feature which was the easiest to compute was retained.

Finally, statistical testing was completed to determine whether or not true pellet size affected the feature values. To do this, 100 food pellets were randomly sampled from each of the available food pellet sizes (2 – 11 mm). Data were first tested for normality and equal variance (Minitab statistical software), as a necessary qualifying condition for parametric statistical methods. None of the measured parameters (measured area, relative contrast, compactness, expected intensity) were found to be normally distributed at the 95% confidence level and only a few of the pellet sizes had equal variance for compactness (none had equal variance for relative contrast or measured area). A one-sample sign test was, therefore, used to see if there were significant differences in value of the median at the 95% confidence level. The one-sample sign test is a non-parametric test, which is similar to the t-test. The primary difference with a one-sample sign test when compared to a t-test is that it does not make any assumptions about the distribution of the data. The disadvantage of using the one-sample sign test in place of the t-test is that the one-sample sign test has wider confidence intervals than a t-test does at equivalent confidence levels.

4.5 Algorithm Validation

Algorithm validation was undertaken to determine the overall accuracy of the pellet detection algorithm and to determine the magnitude of and reason for errors in detecting food pellets. A total of 616 images from 14 different feeding events were collected, representing a range of water quality and fish stocking conditions (see Table 1 for details). In each of the images, pellets were manually counted to determine the number of true pellets in each image. Pellets were counted by examining consecutive video frames to determine which objects were food pellets. Each identified food pellet was then measured by zooming in and manually tracing the pellet outline to determine its total area (pixels). Food pellets with a measured area greater than or equal to the minimum area (30 pixels) for a food pellet were then counted as detectable pellets. Pellets of area less than 30 pixels were not counted as detectable food pellets for three reasons: 1) a large number of non-pellet objects have a smaller area (see Results), 2) smaller objects tend to have fewer measurable features, making it more difficult to distinguish between pellet and non-pellet objects and 3) pellets with area less than 30 pixels were still far from the camera and were often eaten by fish before reaching the camera.

Once all of the visually detectable pellets in an image had been identified, the pellet counting algorithm was executed to determine which objects were identified as pellets by the computer. The number of detectable pellets identified, the number of detectable pellets not identified and the number of false detections (non-pellet objects identified as pellet objects) were counted and recorded. In the case of missed pellets or false detections, the reason for misclassification was determined and recorded.

4.6 Practical Usage (Alarm Triggering and Sampling Rate)

The following criteria were used to develop various methods for triggering a pellet detection alarm and for determining the maximum number of cameras that could be monitored:

1) The maximum number of false detections in a single frame. The fish farming community did not wish to see the system turn off without a pellet loss event occurring (false alarm). The alarm trigger for the maximum number of pellets detected in a single frame was, therefore, set greater than the maximum number of non-pellets ever detected to be conservative.
2) Through discussion with the fish farming community, the system should send a pellet loss alarm as soon as possible when large numbers of pellets are visible (>10) and after no more than 20 seconds when few pellets are visible (3-4 pellets per image frame).
3) The camera sampling rate had to be less than the time it took a food pellet to pass through the camera view area (somewhat camera lens dependent).

4) The amount of time that the maximum number of false detections were within the camera view area was used to develop different filtering methods for suppressing false pellet detections (i.e. if 5 false detections were in the camera view area for 1 s, then a five second average of one sample per second may be sufficient to remove the effect of the false pellets).
5) The system should take into consideration both burst and continuous feeding systems (pellets do not always fall through the view area depending on the feeding method, feed discharge rate and feed spread).
6) The system should be able to detect both a steady stream of a few (2 - 4) pellets per frame as well as a large number (>7) pellets per frame in as short a time period as possible (because both conditions are common in practice).

Three techniques for triggering a pellet detection alarm were developed using the above criteria. All of the triggering methods were based on records of the worst-case conditions for false detections found in the test footage. The resulting triggering methods were tested using two sampling rates: 2 frames per second and 0.5 frames per second. The 2 frames per second sampling rate represented the fastest possible rate at which the test computer could execute, while 0.5 frames per second sampling rate was selected based on the amount of time that it took a food pellet to fall through the camera view area.

The characteristics of the worst-case conditions (false detections) are as follows: Non-pellet material sank at a slower speed than food pellets (see Section 4.3.4) and, therefore tended to be present in video frames for a longer period of time than food pellets. Also, the number of false detections tended to be unpredictable in time and usually occurred in short bursts. False detections (especially large numbers) were not usually present at the same time as true pellets and were considered to constitute impulsive noise.

One very useful and simple approach to removing impulsive noise is the median filter (Vaseghi, 1996). The advantage of a median filter is that it is insensitive to outlier points (unusually large or small). Useful features of median filters are that they tend to preserve signal edges, are simple to compute and do not require a large number of samples. The disadvantage of median filters, is that in actual application, they tend to distort some types of signals, particularly when noise is present in the signal for several samples in duration (Vaseghi, 1996). When triggering pellet alarms, reliable and fast detection of the rising edge of a pellet loss signal was considered most important, so median filters were selected to process the pellet detection signal. In addition, a median filter is capable of sending an alarm when 50 + 1% of the samples contain the desired signal (e.g. for a five point median filter, an alarm could trigger after 3 consecutive samples of a rising edge were collected).

More advanced methods of noise reduction were not found to be effective as they tended to require a large number of samples to be collected or some prior knowledge as to the form of the noise signal (i.e. Fourier transform, see Section 3.2.2).

Based on the properties of the median filter, and the alarm triggering criteria (Section 4.6), five pellet alarm triggering methods were tested: single frame, three-sample median, five sample median, seven sample median and nine sample median. Several triggering methods were selected to satisfy criteria 5 (trigger an alarm as fast as possible). Shorter length filters tended to detect higher intensity pellet loss in a shorter time-frame than longer length filters.

4.7 Dynamic Validation

As a final validation step, the final pellet detection program including triggering was run, using videotaped footage of feeding events to compare the reaction time of the pellet detection system to that of a farm worker manually viewing a video monitor and to determine the number of cameras that could be monitored simultaneously. It was arbitrarily assumed that the farm worker would choose to make a feed control decision (decrease feeding rate or stop feeding) when 4 detectable pellets were viewed in a single image and would take an additional 5 seconds to act on the feed control decision. It was assumed that the pellet detection system would immediately stop or slow a feeder when pellets were detected.

In total, 20 episodes of pellet loss, lasting up to one minute in duration and representing 5 low (< 5 kg/m^3), 5 medium (> 5 - < 10 kg/m^3) and 10 high (> 10 kg/m^3) stocking density cases were tested. For each pellet loss episode, tests were conducted with a 0.5 and a 2 second sampling rate. For each test, the average number of seconds to trigger a pellet loss alarm was measured at the 95% confidence level (n = 10). Also, for each pellet loss episode, the number of detectable pellets was manually sampled every second to estimate the magnitude and duration of each pellet loss event.

The results from the dynamic validation exercise were used to determine the minimum required sampling speed per camera and thus, the maximum number of cameras that could be sampled by the test computer.

5.0 Results

This section presents the results and data collected for the development of the pellet detection algorithm, for the static (single frame) validation and for the final system testing using live video footage.

5.1 Details of the Pellet Recognition Algorithm

5.1.1 Threshold step value (I_{STEP})

The threshold step value influenced the success of pellet detection and the image processing speed. Figure 5 shows the relationship between the number of pellets detected (before classification) and the threshold step value. Detection was optimum at a threshold step of one and decreased linearly. At a threshold step of five, 95 ± 5% of pellets were detected ($\alpha = 0.05$, $n = 20$). Figure 6 shows the relationship between the time that a 0.95 GHz Pentium III computer took to process a standard image and the threshold step value. Increasing the step value decreases the overall time that it takes to process an image. Threshold step value was considered important because it was the primary factor associated with image processing speed. At a threshold step value of 5, image processing related to thresholding accounted for approximately 75% of the total image processing time.

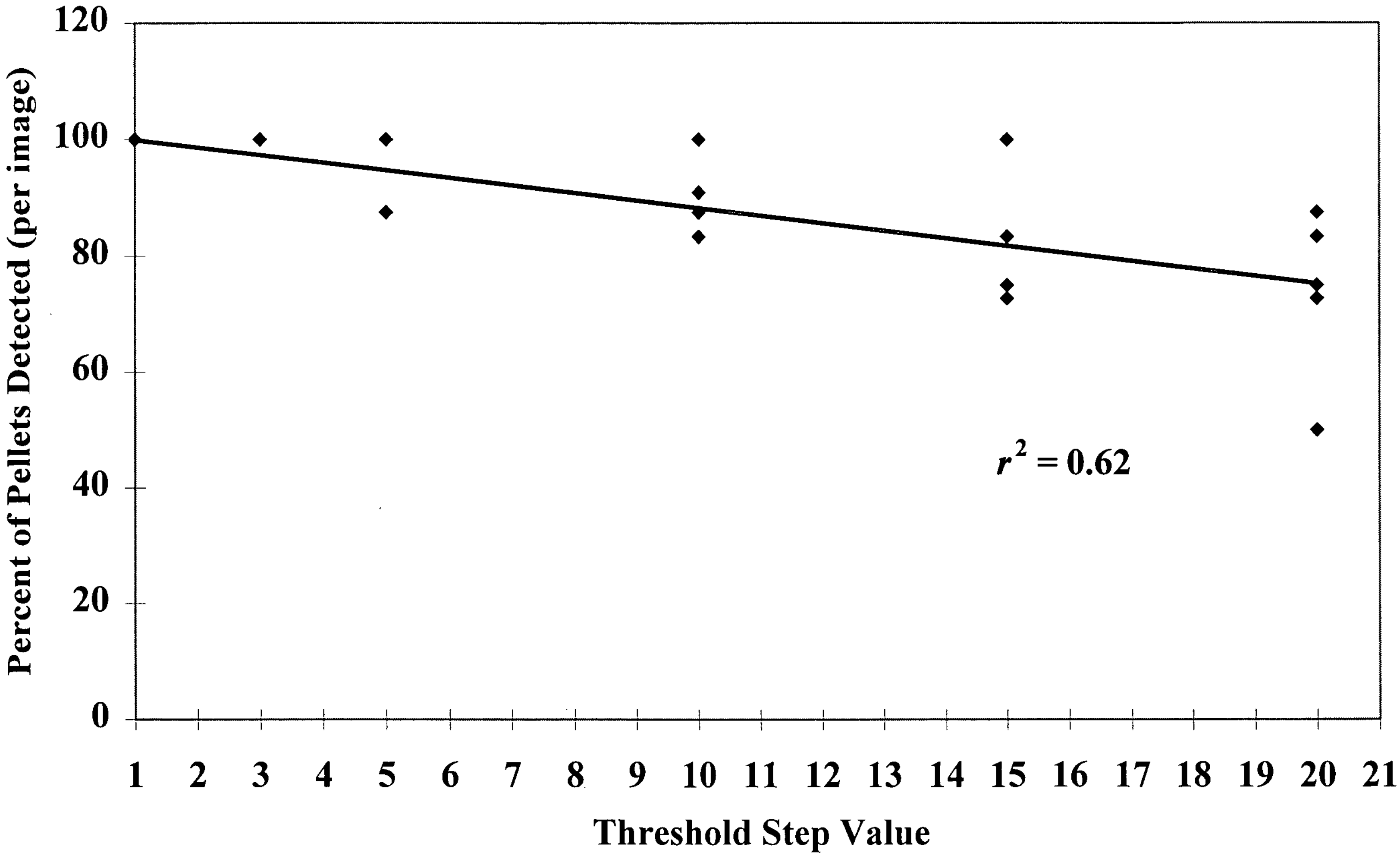


Figure 5: Effect of threshold step value on number of detected pellets (5 images per step value were sampled).

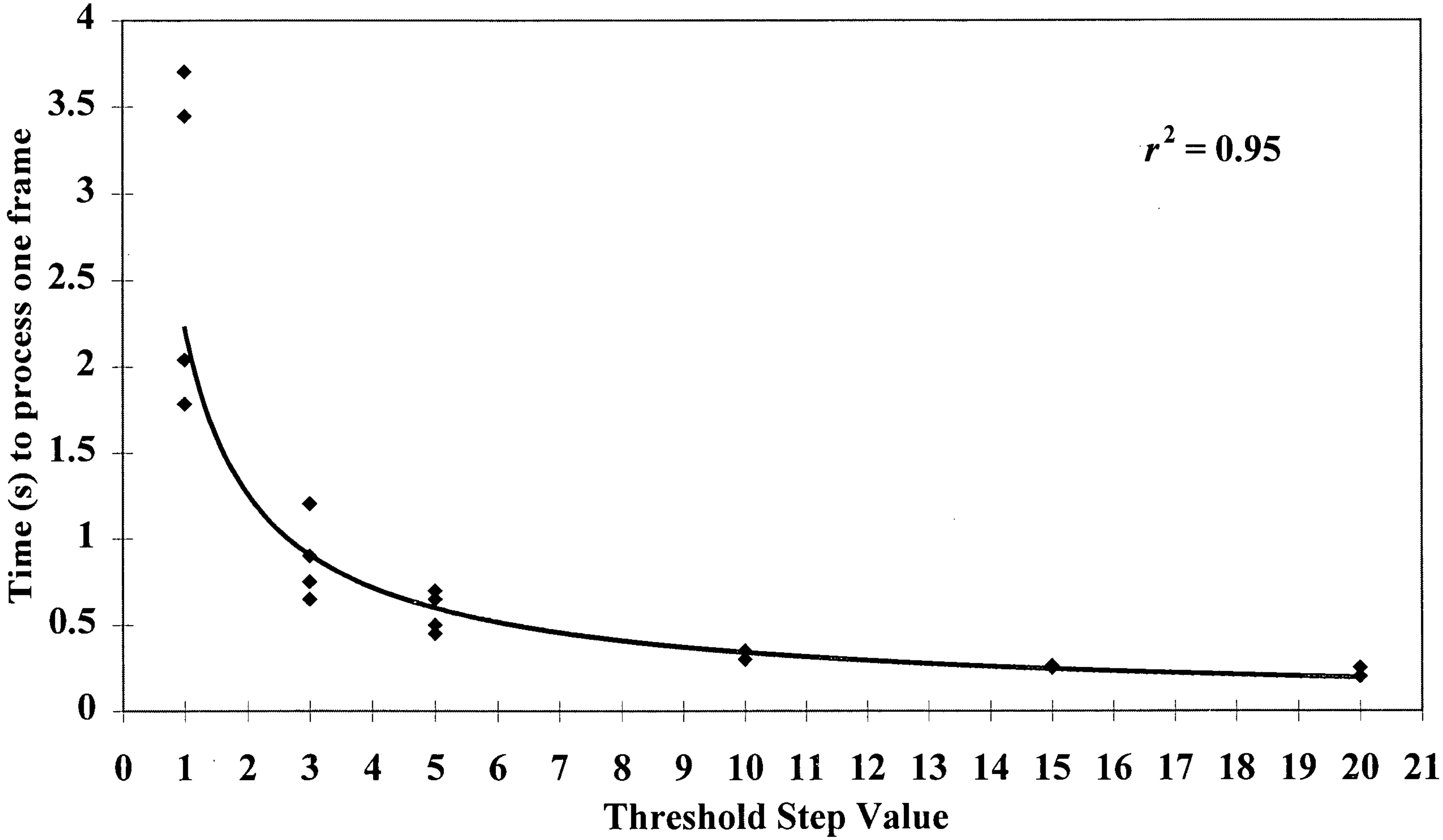


Figure 6: Effect of threshold step value on image processing time (5 images per step value were sampled).

5.1.2 Pellet feature descriptors

The following graphs show the distributions of pellet and non-pellet objects (primarily waste matter) in the form of a cumulative histogram. Separation of pellets from non-pellets (percent of pellets detected minus percent of non-pellets detected) was calculated to illustrate the ability of each feature descriptor to distinguish between pellet and non-pellet objects. For example, in Figure 10, the percent separation of pellets from non-pellets was calculated by subtracting the number of non-pellets retained from the number of pellets retained in the following fashion:

1) At $1.3 \leq C \geq 1.65$, 97% – 2% = 95% of pellets retained.
2) At $1.3 \leq C \geq 1.65$, 35% – 10% = 25% of non-pellets retained.
3) Overall separation of pellets from non-pellets is 95% - 25% = 70%.

The non-pellet objects tended to have a smaller measured area than pellet objects (Figure 7). In general, the non-pellet objects tended to have a much higher elongation than pellets (Figure 8). The theoretical minimum possible elongation of any object is 1.0. Approximately 18% of pellet and 6% of non-pellet objects had an elongation equal to 1.0. Pellet objects tended to have lower values of roughness and compactness than non-pellet objects had (Figures 9 and 10). The theoretical minimum for compactness and roughness is 1.0. The general trend for relative contrast (RC) was that pellets tended to have a higher relative contrast when compared to non-pellet objects (Figure 11). Pellets also tended to have a higher sinking speed than non-pellet objects (Figure 12). Sinking speed was not used in the pellet recognition algorithm as the sinking speed measurement required two consecutive image frames to be processed (see Discussion). Non-pellet objects tended to have a larger difference between expected and actual intensities when compared to pellet objects (Figure 13). Equation 13 appeared to accurately represent the intensity vs. distance curve (distance from camera is inversely proportional to measured area) for pellet objects (Figure 14). Overall, an examination of the feature data showed that while complete discrimination of pellet and non-pellet objects was not possible, there was a sufficient degree of discrimination. The remaining (non-separable) non-pellet objects were considered false detections and taken into consideration when developing the alarm triggering methods (Section 5.3).

The independence of the remaining features (measured area, elongation, roughness compactness, relative contrast and expected intensity) were tested for correlation using the Pearson method (Minitab statistical software). The results (Table 2) show that the three shape descriptors: elongation, roughness and compactness are all highly correlated ($p < 0.05$).

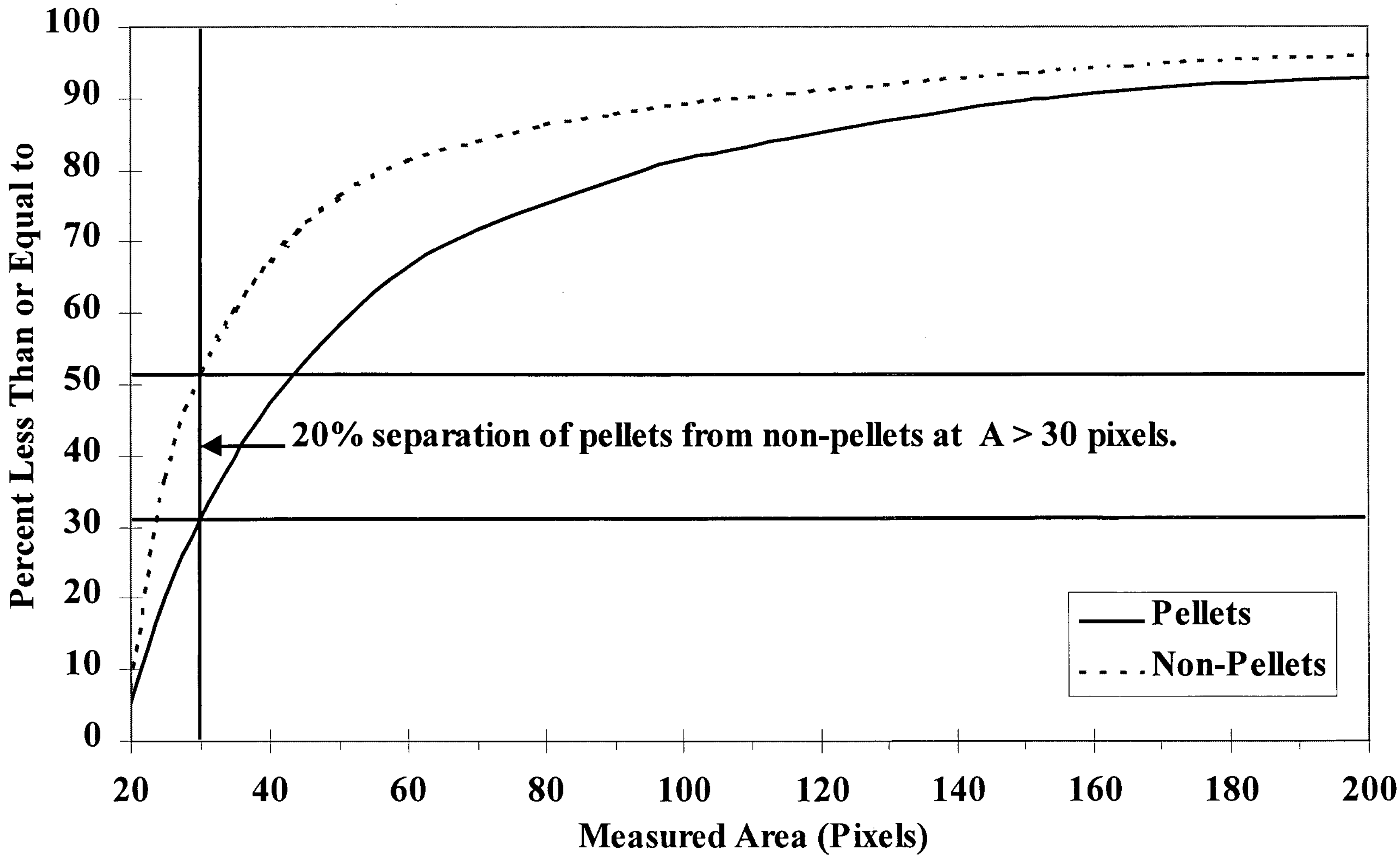


Figure 7: Measured area of pellet and non-pellet objects ($n = 1000$, as measured by the computer).

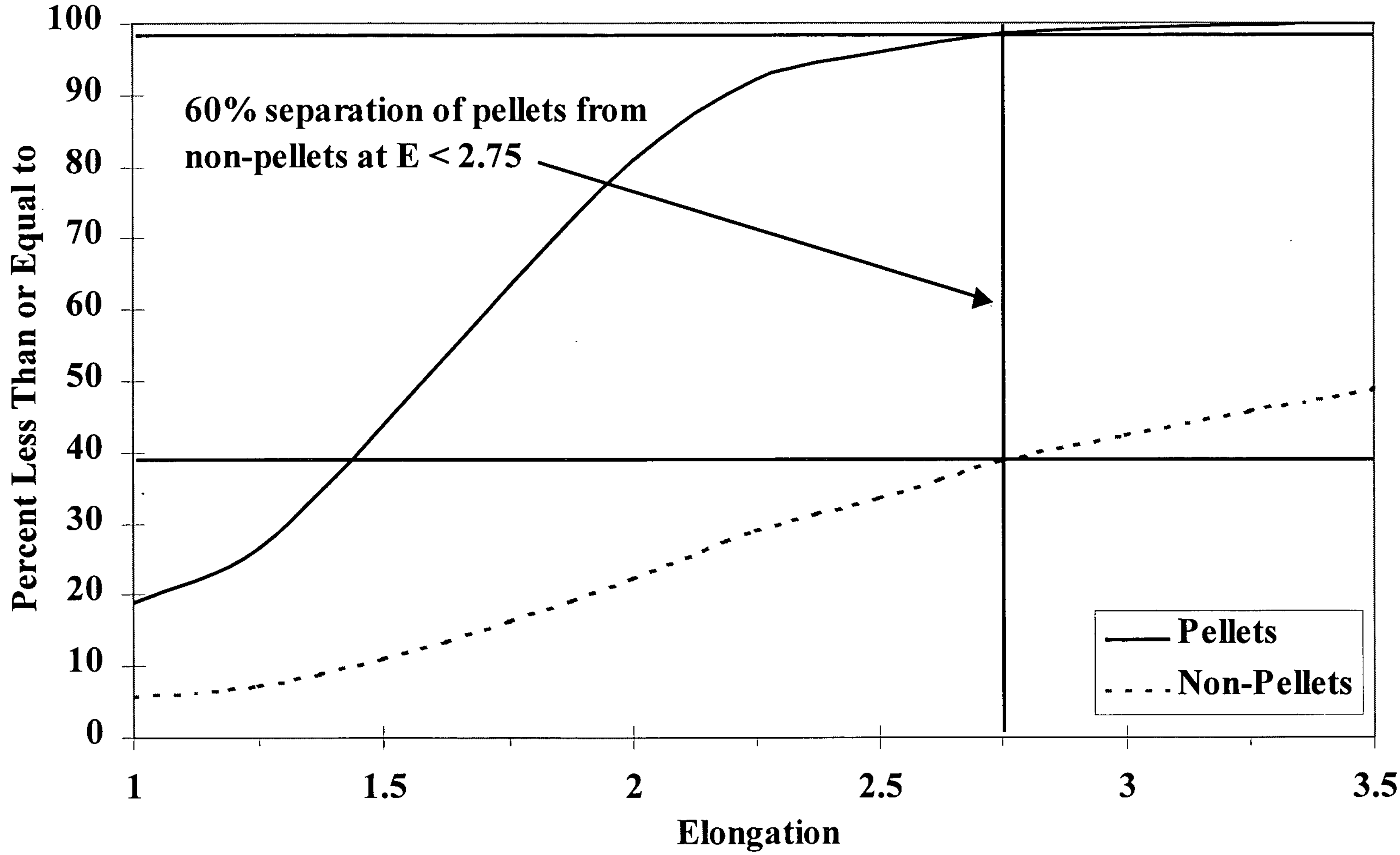


Figure 8: Elongation of pellet and non-pellet objects ($n = 1000$, as measured by the computer).

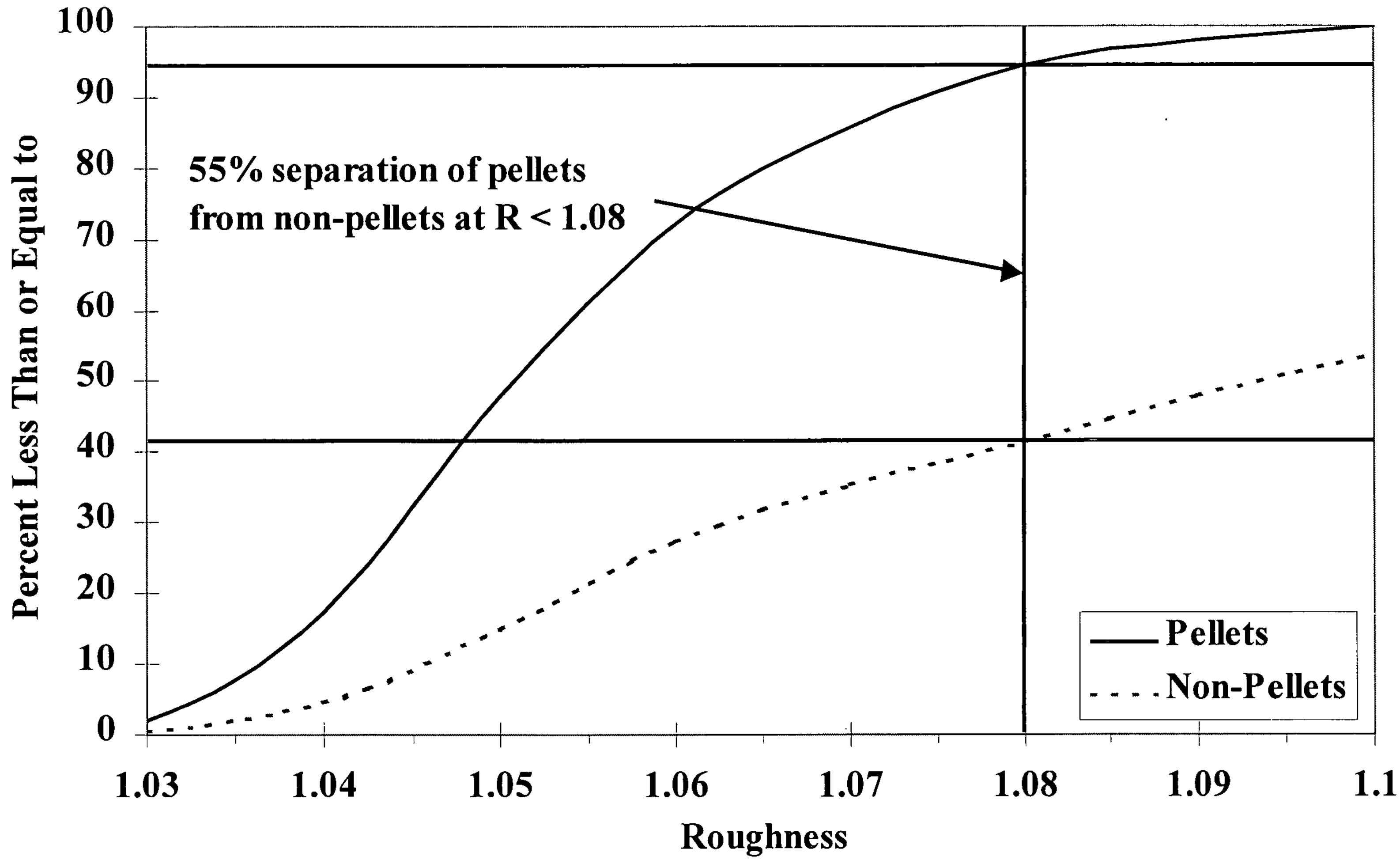


Figure 9: Roughness of pellet and non-pellet objects (n = 1000, as measured by the computer).

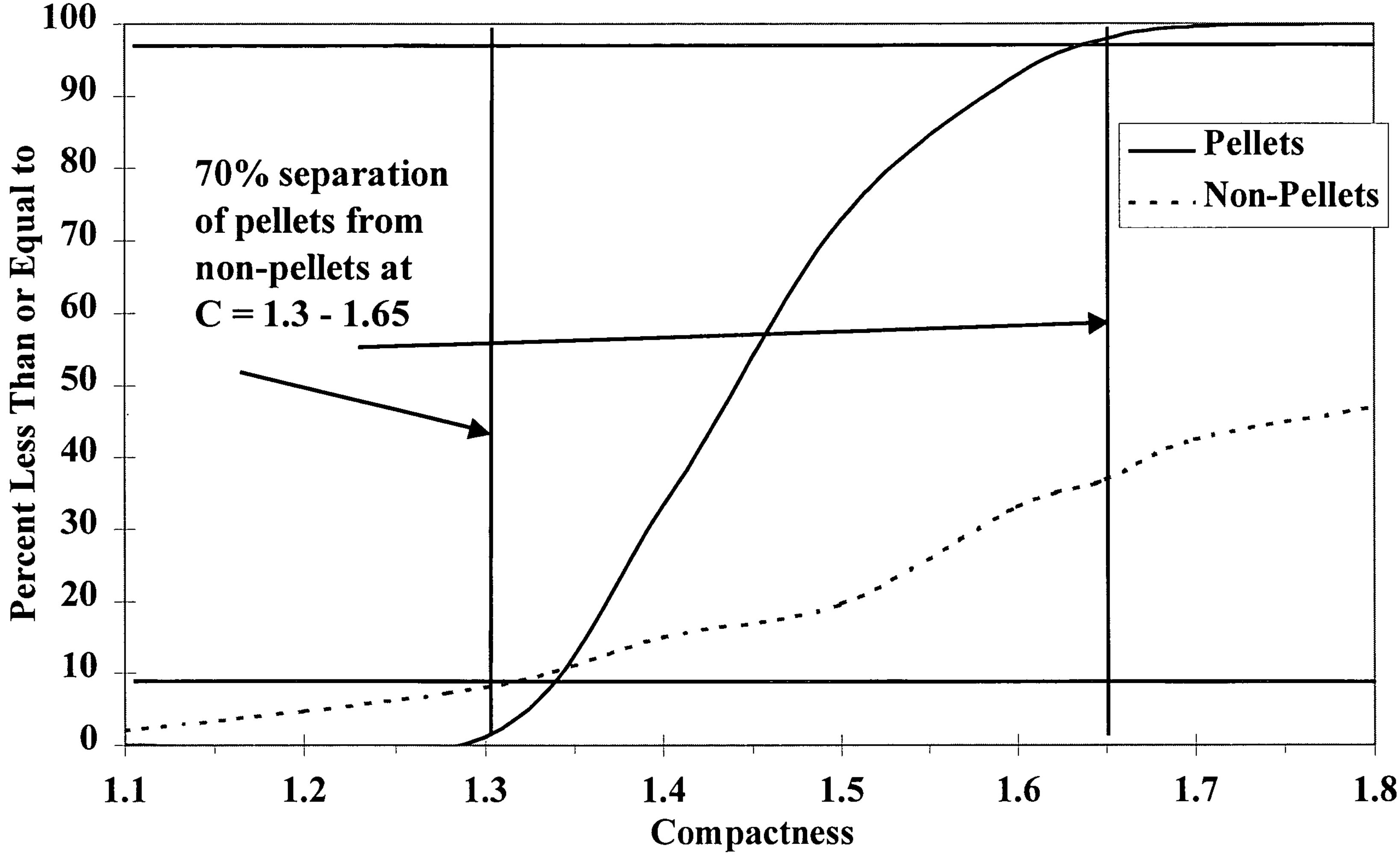


Figure 10: Compactness of pellet and non-pellet objects (n = 1000, as measured by the computer).

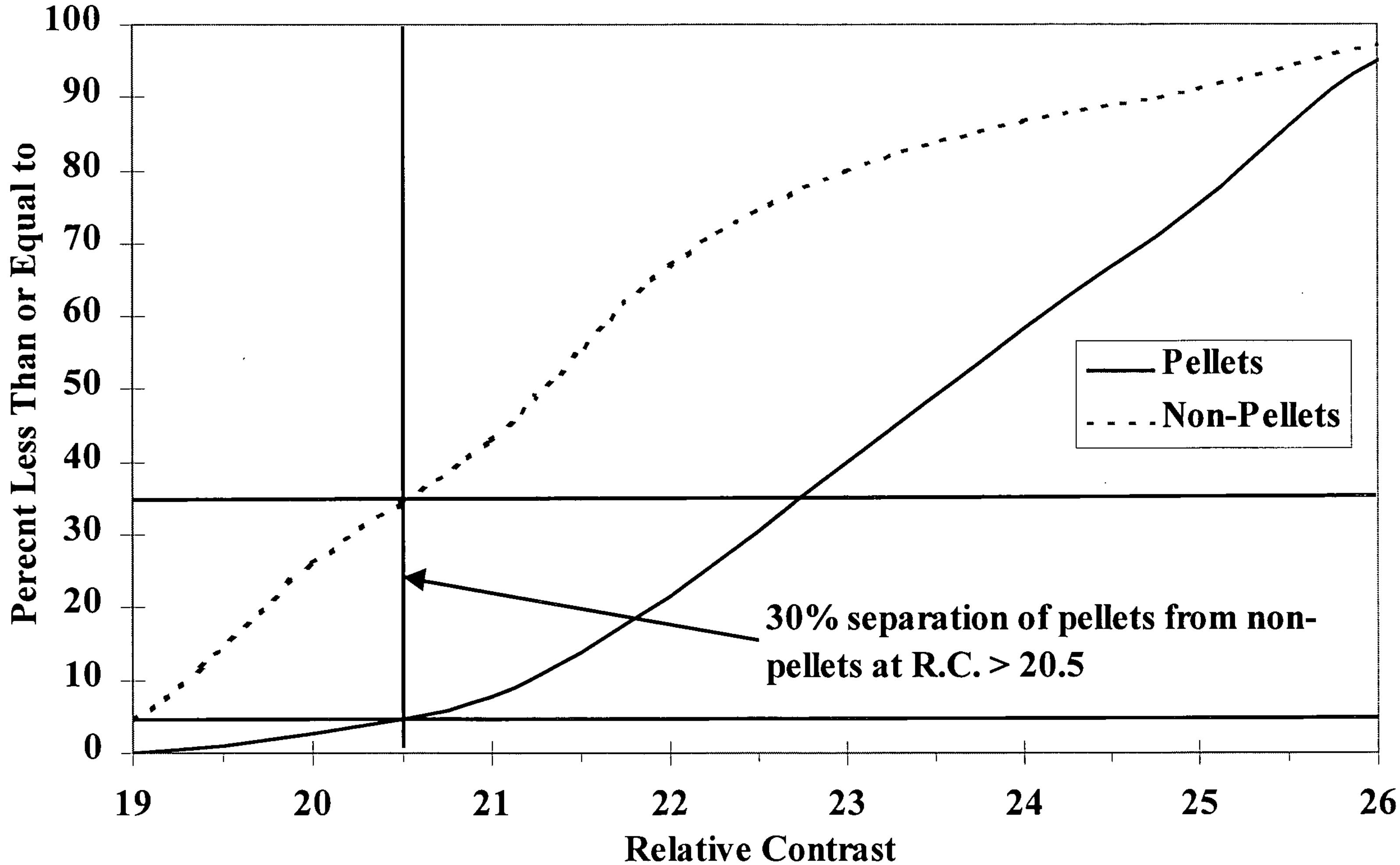


Figure 11: Relative contrast of pellet and non-pellet objects (n = 1000, as measured by the computer).

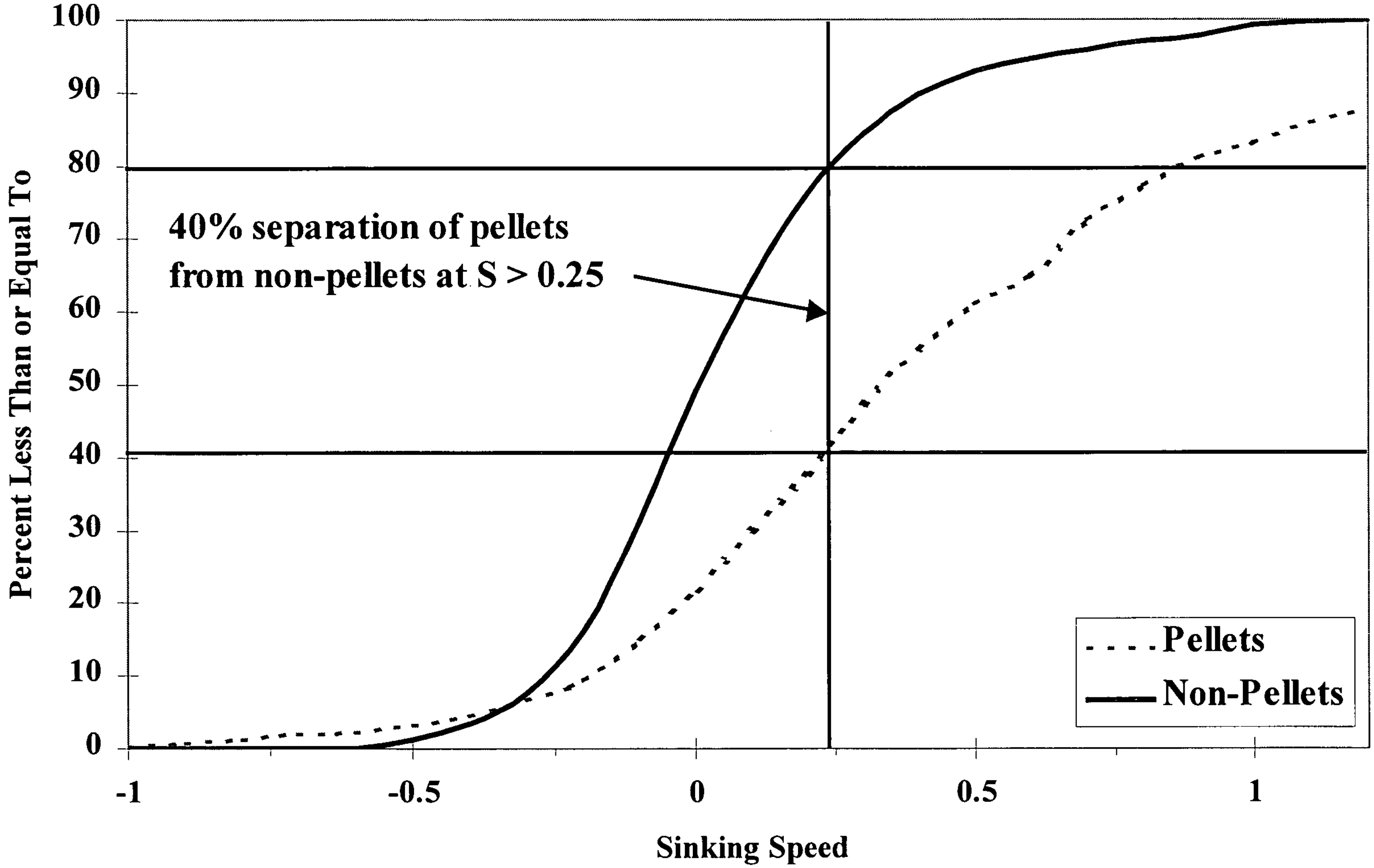


Figure 12: Sinking speed of pellet and non-pellet objects ($n = 400$, as measured by the computer).

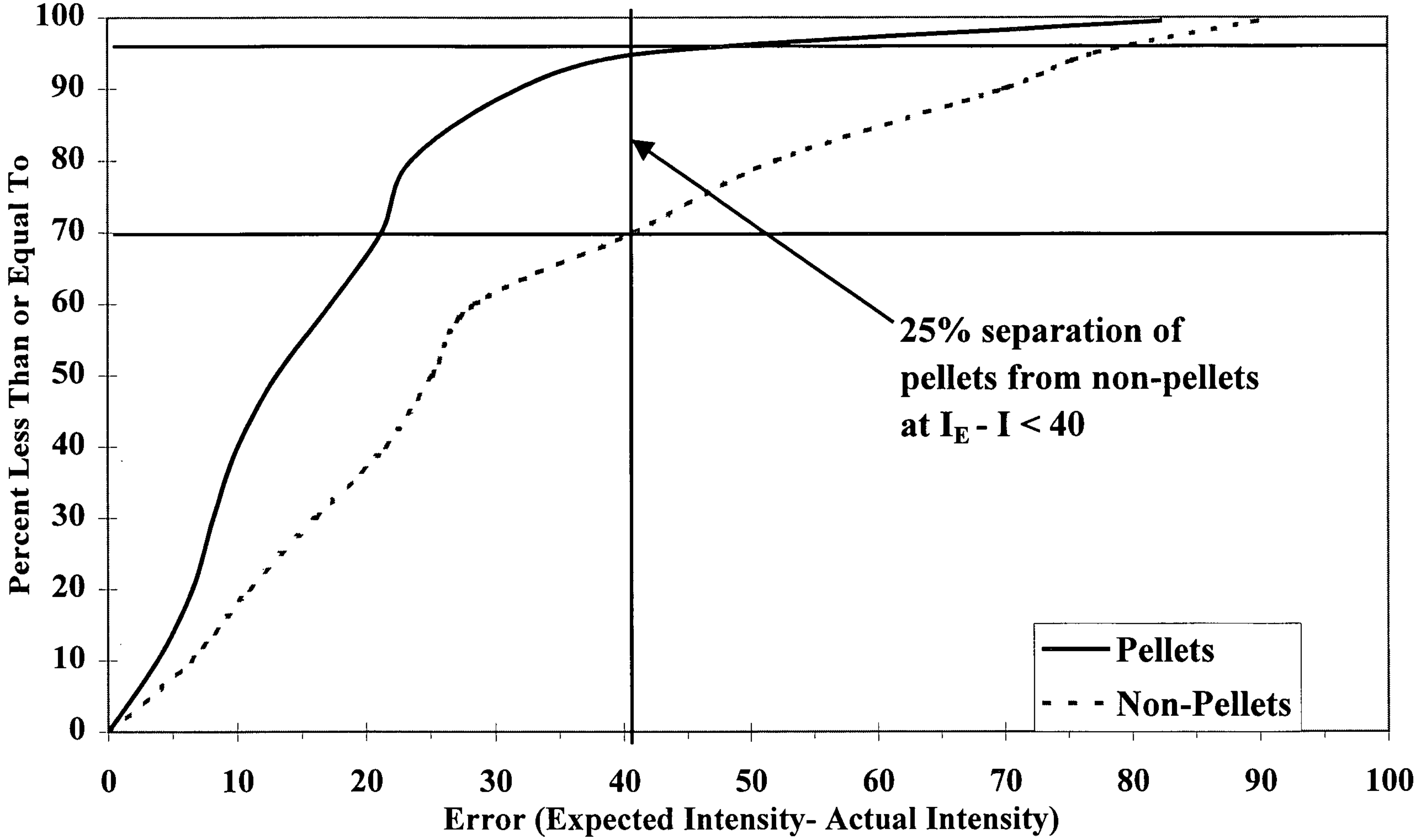


Figure 13: Expected intensity of pellet and non-pellet objects (n = 200, as measured by the computer).

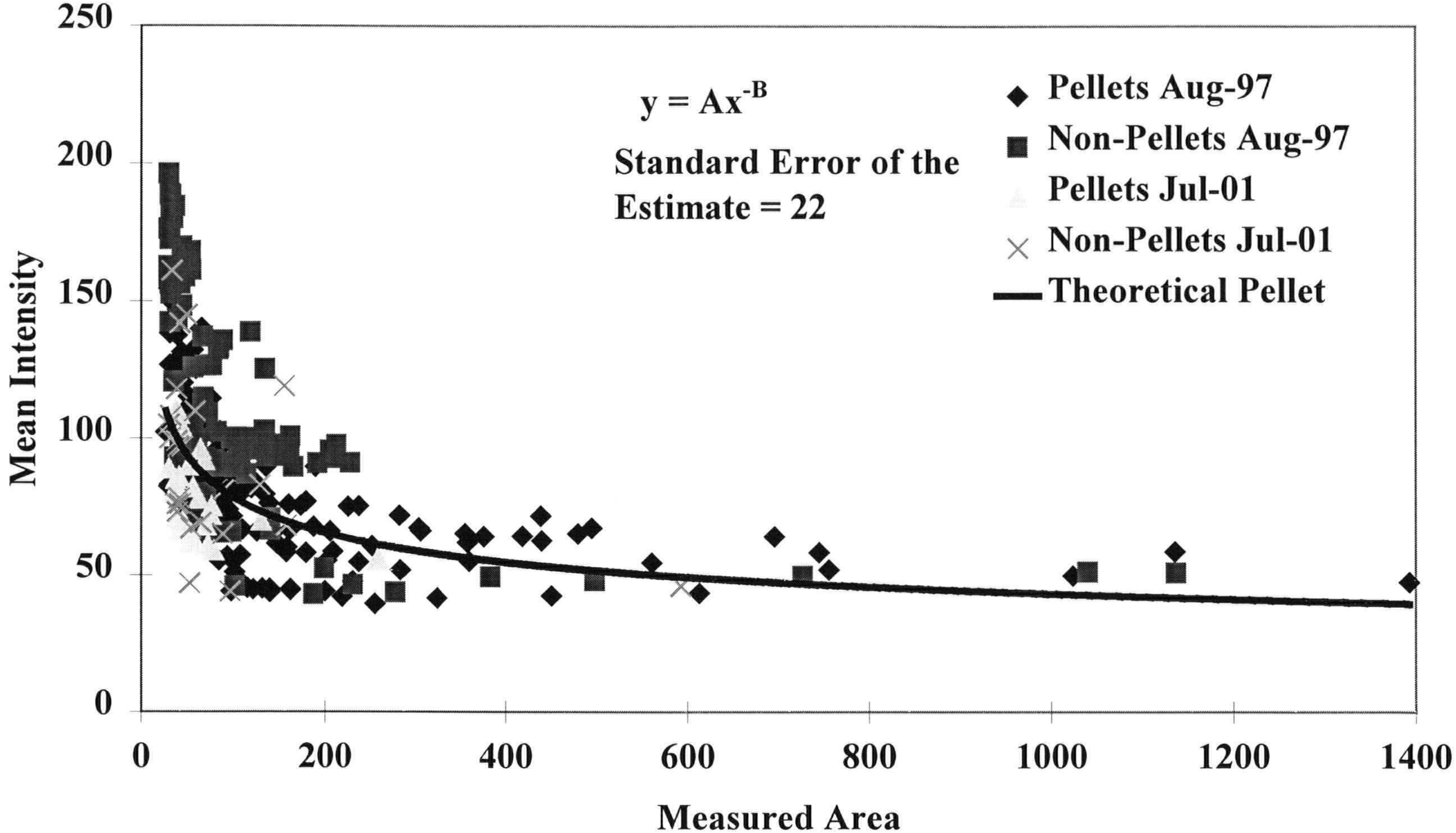


Figure 14 (A): Measured area vs. intensity for pellet and non-pellet objects ($n = 216$ for pellets, $n = 116$ for non-pellets). A and B were determined by experimentation.

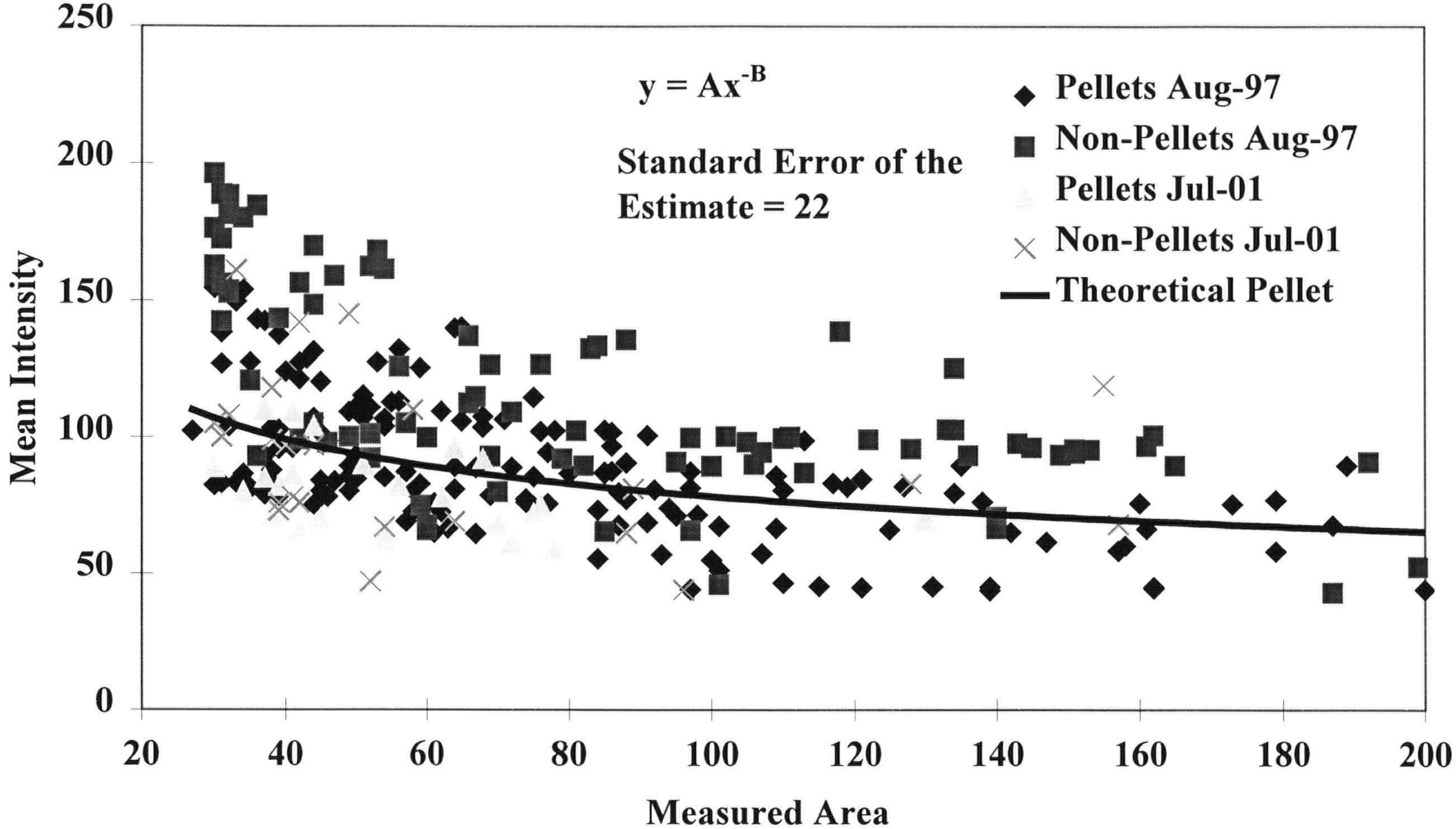


Figure 14 (B): Measured area vs. intensity for pellet and non-pellet objects showing detail in the area = 30 -200 pixel region.

Based on the results in Table 2, area, relative contrast, expected intensity and compactness were selected as the features for pellet classification. To test whether or not any of the pellet classification features were dependent on the actual food pellet diameter, a one-sample sign test was completed. No significant differences in the median of any of the features were found for different sizes of pellets. Figures 15-18 show the results for each of the features: measured area, relative contrast, compactness and expected intensity.

Table 2: Probability (*p* - value) that features are correlated using Pearson correlation.

	Area	Relative Contrast	Elongation	Roughness	Compactness	Expected Intensity
Area	-	0.407	0.218	0.178	0.232	0.115
Relative Contrast		-	0.865	0.319	0.232	0.155
Elongation			-	<0.001	<0.001	0.678
Roughness				-	<0.001	0.580
Compactness					-	0.639

Classification of objects was completed by using a logical AND equation, where an object had to fall within the accepted bounds of each classification feature to be identified as a food pellet.

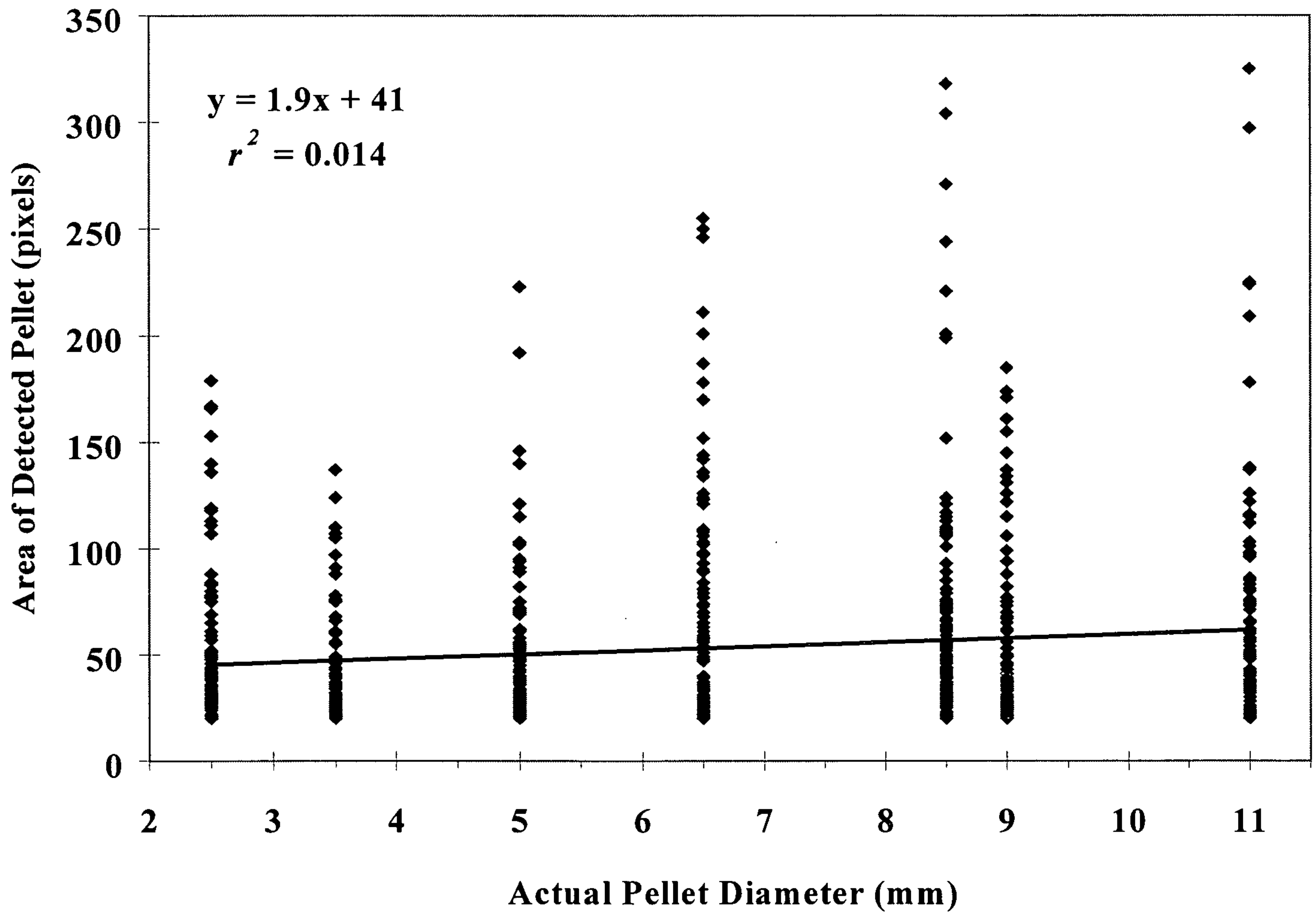


Figure 15: Measured area vs. actual pellet diameter ($n = 100$ for each pellet size).

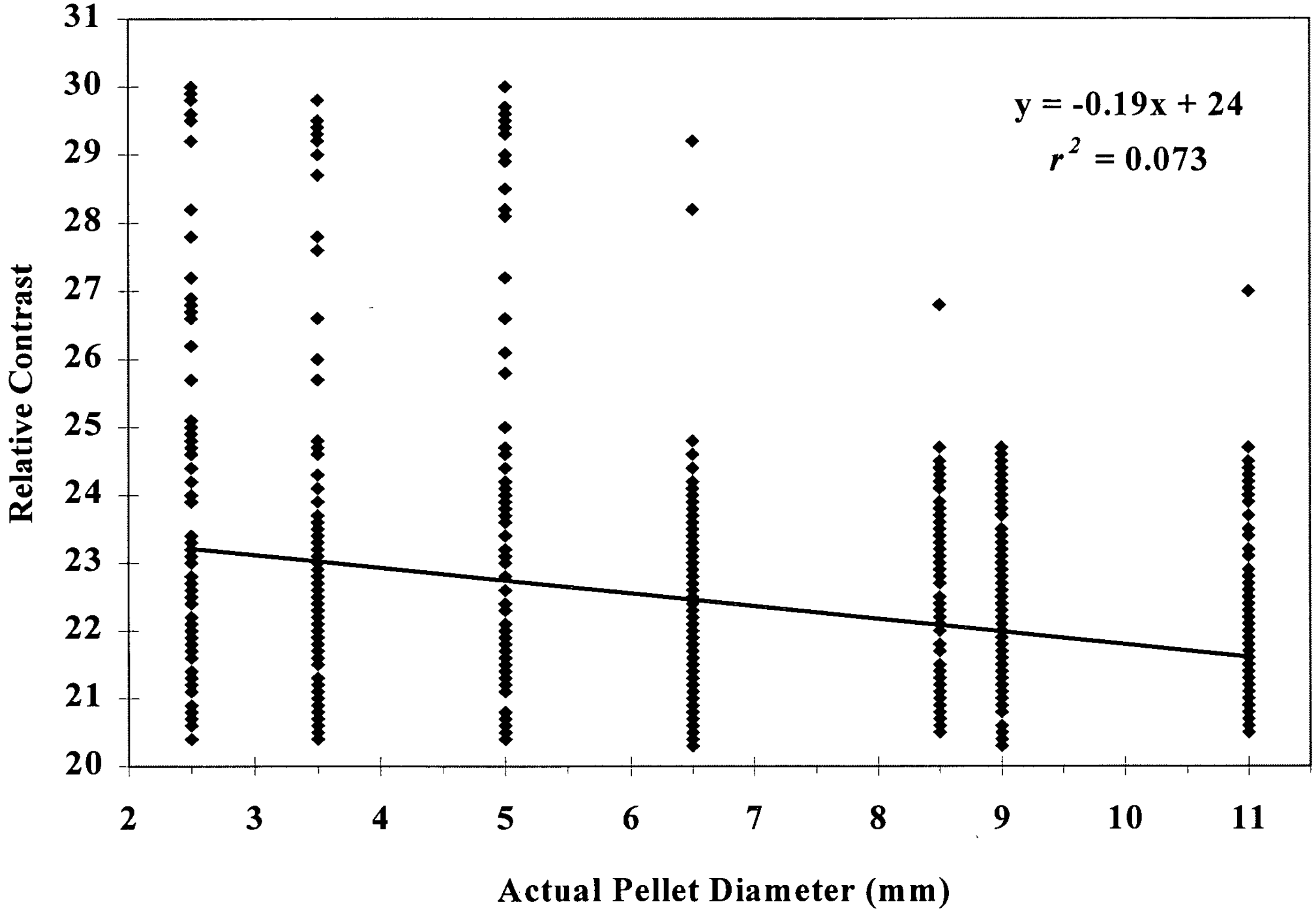


Figure 16: Relative contrast vs. pellet diameter (n = 100 for each pellet size).

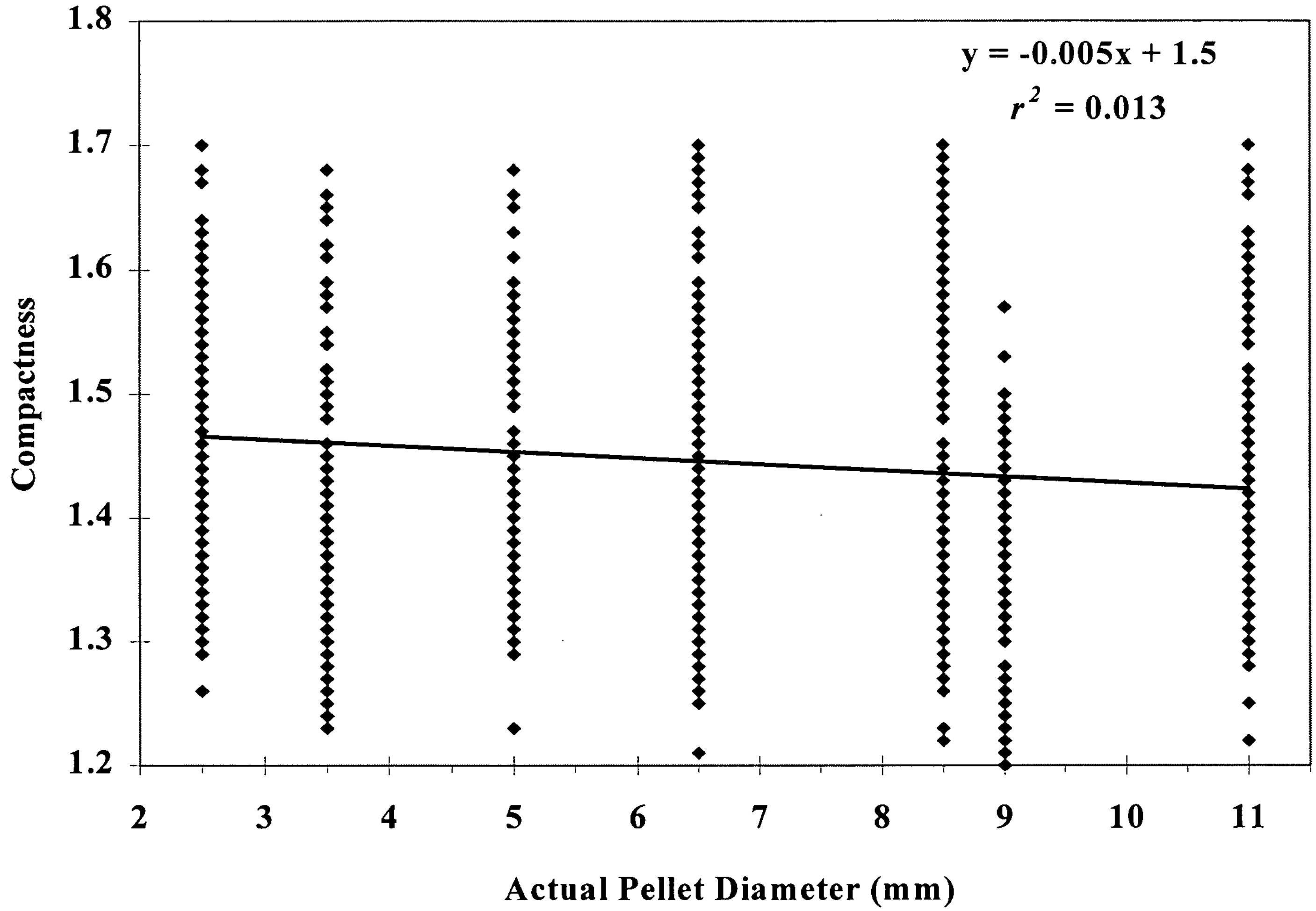


Figure 17: Compactness vs. pellet diameter (n = 100 for each pellet size).

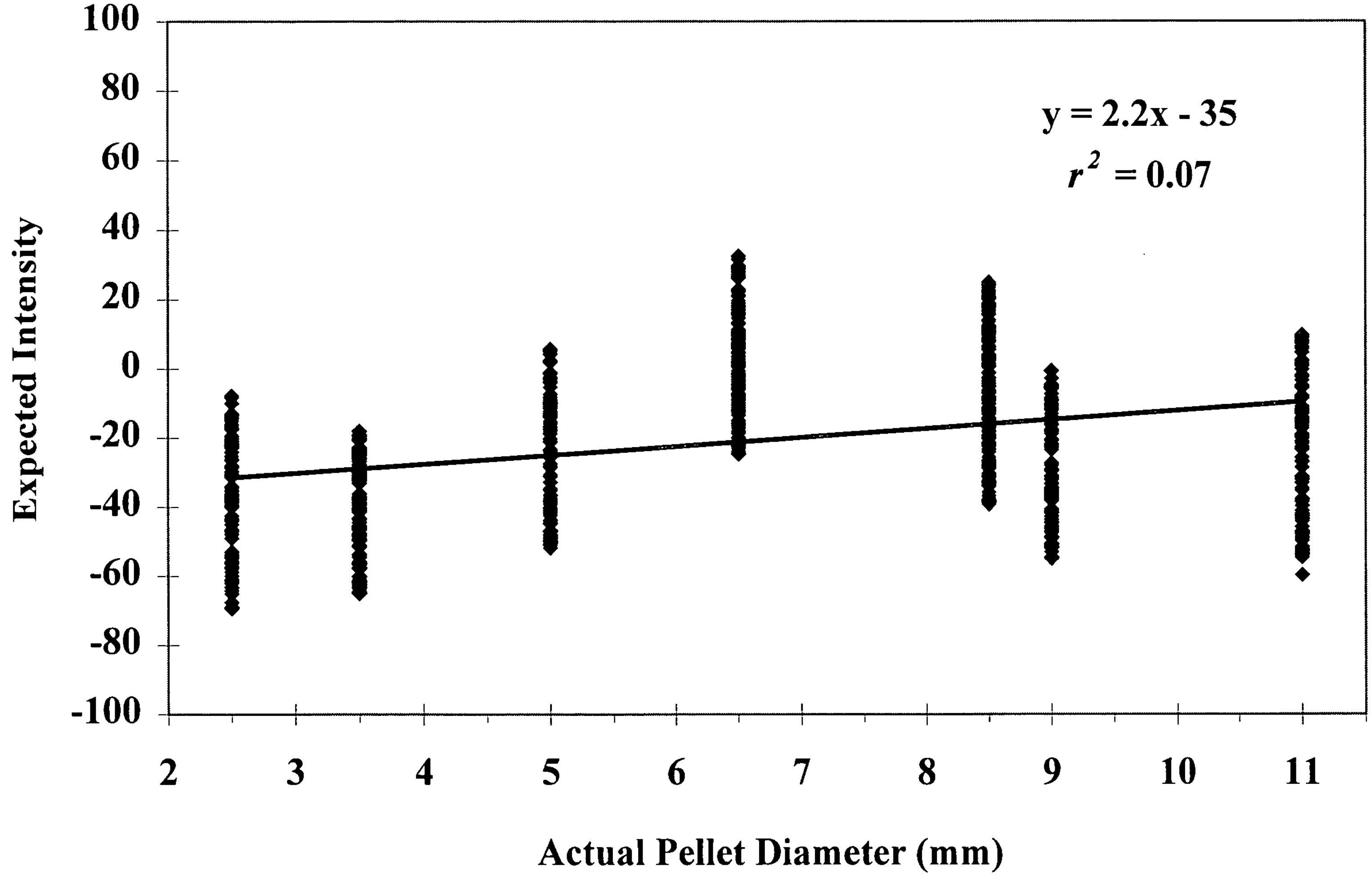


Figure 18: Expected intensity vs. pellet diameter (n = 100 for each pellet size).

5.2 Static Validation

Static (single frame) validation was carried out on 616 images from 14 different netcages (44 images per netcage). Each image was examined and pellets were manually counted and compared to computer pellet counts. Tables of results can be found in Appendix A.1. Table 3 shows the detection results for detection undertaken on the odd field, even field and the summation of both fields (each video frame consists of two fields, odd and even, see Section 4.3.2). The average number of pellets detected for all samples was 84%. Figure 19 shows a cumulative histogram of the percentage of true pellets detected per image. From the figure, the median pellet detection rate was 100%, while 95 % of all images tested had a pellet detection rate greater than 50%

Table 3 also shows the average and maximum false detections for detection using both fields. The average number of false detections per frame ranged from 0.07 to 2.3 depending on the date sampled.

Figure 20 shows the difference between the true number of pellets (measured area ≥ 30 pixels) in each image and the computer pellet count. From the figure, one can see that the computer pellet count tends to be slightly higher than the actual pellet count for images with few detectable pellets (<3) and tends to be lower than the actual pellet count for images containing a larger number of detectable pellets (>3).

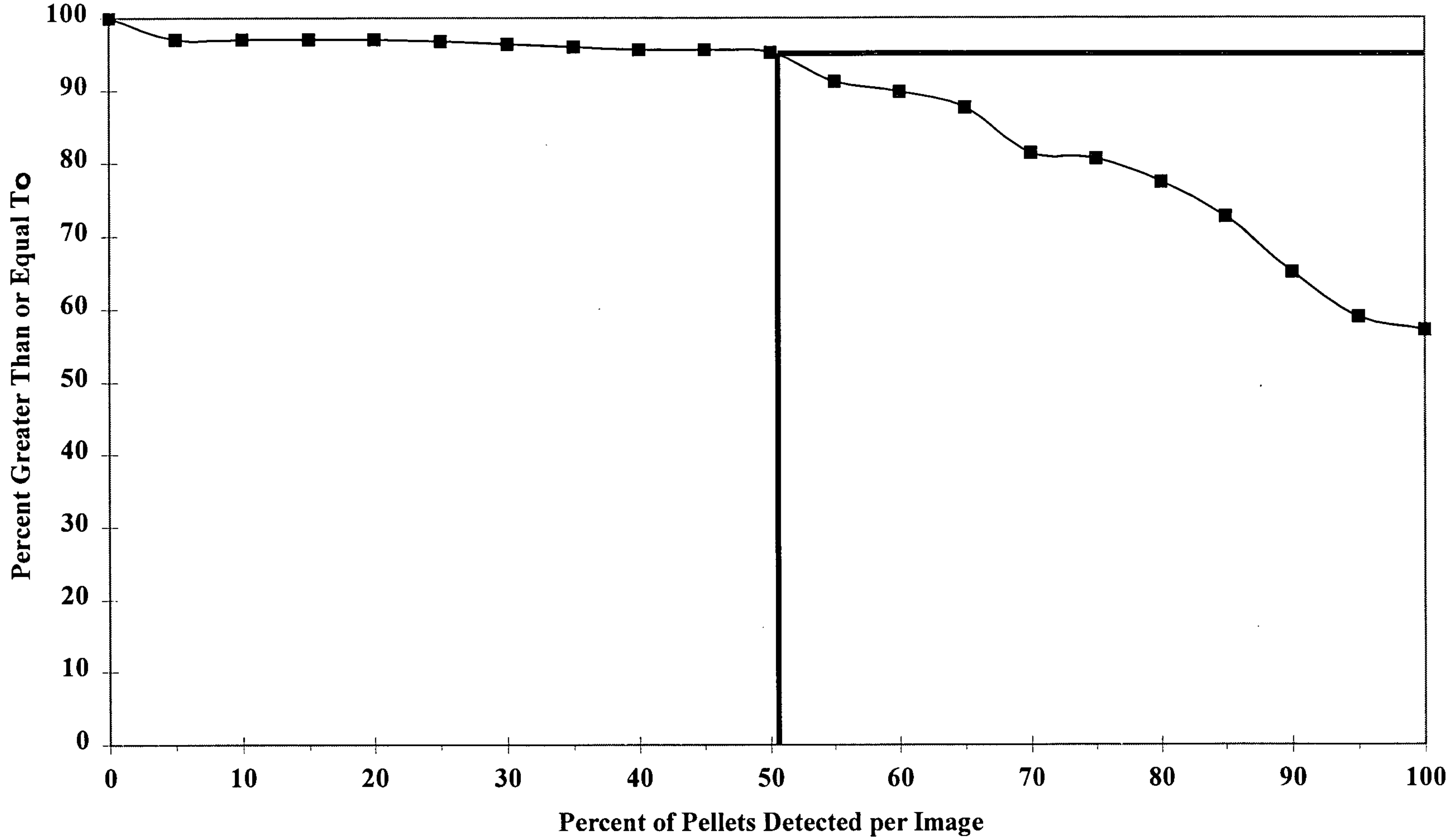


Figure 19: Cumulative histogram showing the percent of images sampled vs. the percent of true pellets detected per image.

Table 3: Comparison between using odd, even or both fields for detection and the resulting false detection rate (n=44 for each date).

Date	Total # of Pellets	% of True Pellets Detected			Both Fields Only		
		Odd Field	Even Field	Both Fields	Total # of False Detections	Avg. # of False Detections Per Frame	Max. # of False Detections Per Frame
July 29/94	0	N/A	N/A	N/A	48	1.1	4
Oct 10/94	174	77	79	95	12	0.27	1
Aug 5/97	52	69	69	83	30	0.68	2
Aug 6/97	73	60	55	77	20	0.45	3
Aug 7/97	6	50	83	83	63 (**57***)	1.4 (**1.3***)	6 (**5***)
June 27/00	100	58	69	79	35 (**34***)	0.78 (**0.77***)	3
June 28/00	236	62	62	81	3	0.07	2
June 27/01	1	100	100	100	28	0.64	3
July 11/01 A	45	69	67	78	24 (**20***)	0.55 (**0.45***)	3
July 11/01 B	35	61	65	66	35	0.80	3
July 12/01 A	155	66	69	77	18 (**15***)	0.40 (**0.34***)	2
July 12/01 B	89	75	71	89	44 (**40***)	1.0 (**0.91***)	4
July 13/01	415	88	84	96	100 (**7***)	2.3 (**0.16***)	6 (**2***)
Total	**1381**	**70**	**73**	**84**	**460 (349*)**	**0.75 (0.57*)**	**6 (5*)**

(*) Numbers in parenthesis are for non-avoidable false positives only (waste matter and fish).

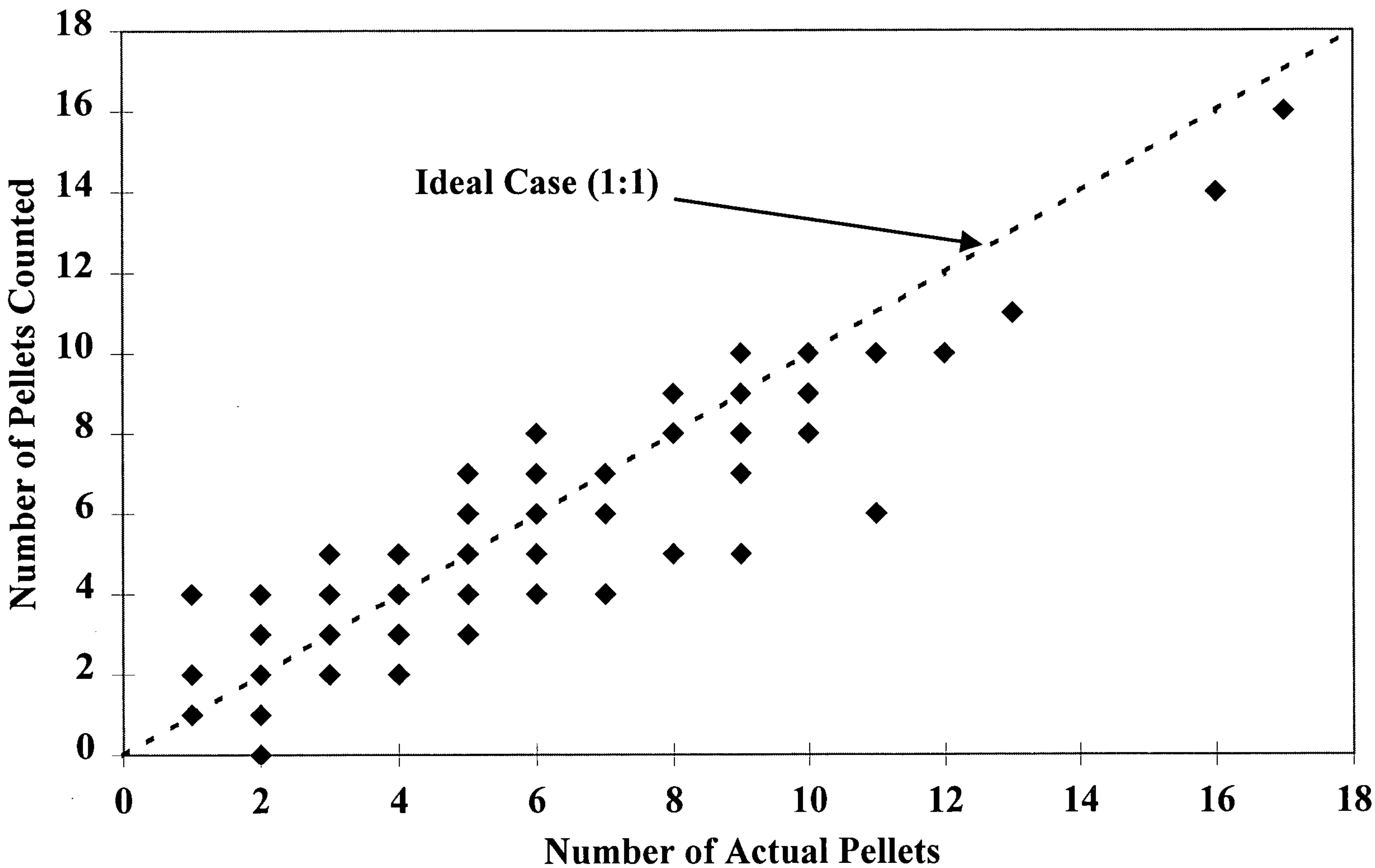


Figure 20: Number of actual pellets (≥ 30 pixels measured area) vs. the number of pellets detected by the pellet detection algorithm ($n = 215$).

Table 4 shows the number and type of false positive detections for each sample. Waste matter accounted for 65% of all false positive detections, followed by the camera at 24%, fish at 11%, and the net at 0.2%. False detections attributed to the camera were considered avoidable because they could be prevented by cleaning the camera lens and ropes. All other false detections were considered unavoidable.

Reasons for false positives were as follows:

1) Fish – detected a portion of a fish (usually a fin or tail).
2) Waste – detected a piece of waste matter.
3) Camera – detected a portion of the camera housing or cable (includes growth of algae on the camera cables).
4) Net – detected portions of the net or growth on the net when billowed into the camera view area.

Table 4: Numbers of and reasons for false detections.

Date	Fish	Waste	Camera	Net
July 29/94	2	46	0	0
October 10/94	11	1	0	0
August 5/97	3	27	0	0
August 6/97	6	14	0	0
August 7/97	6	51	6	0
June 27/00	0	34	1	0
June 28/00	0	3	0	0
June 27/01	4	23	0	1
July 11/01 A	9	11	4	0
July 11/01 B	1	34	0	0
July 12/01 A	5	10	3	0
July 12/01 B	3	37	4	0
July 13/01	1	6	93	0
Total	**51**	**297**	**111**	**1**
Percent	**11.1%**	**64.6%**	**24.1%**	**0.2%**

Data for non-detection of pellets was also collected. Table 5 shows the numbers and reasons for non-detection of pellets in each sample. Pellets on fish accounted for 91% of all missed pellets, while improper shape accounted for 7% and overlapping pellets accounted for 2% of all missed pellets.

Reasons for missed pellets were as follows:

1) On Fish – pellet on or touching the edge of a fish.
2) Shape – pellet shape (or other classification feature excluding area) outside of bounds to be classified as a pellet.
3) Overlapping – two or more pellets overlap, making them undetectable.

Table 5: Numbers of and reasons for missed pellets.

Date	On Fish	Shape	Overlapping
July 29/94	0	0	0
October 10/94	10	1	0
August 5/97	8	1	0
August 6/97	17	0	0
August 7/97	1	0	0
June 27/00	8	2	0
June 28/00	42	0	4
June 27/01	0	0	0
July 11/01 A	9	1	0
July 11/01 B	29	1	0
July 12/01 A	8	0	0
July 12/01 B	40	7	0
July 13/01	5	1	0
Total	**177**	**14**	**4**
Percent	**91%**	**7%**	**2%**

5.3 Alarm Triggering and Sampling Speed

One of the requirements for the pellet detection system was that it should not trigger a pellet alarm unless food pellets are present. Results from tests on the use of different median filters to suppress false detections indicated that different filters were useful depending on the situation. Raw data from the test runs are given in Appendix A.2. Tables 6 and 7 show the maximum filter values for test footage of pellet events and false detections at sampling speeds of 0.5 and 2 frames per second. In Table 7, the burst pellet event corresponded to 2 – 10 detectable pellets per image frame for 10s and the low intensity pellet event corresponded to 0 – 6 (average of 3) detectable pellets per image frame for 60s (see Appendix A.2).

Table 6: Maximum values of filters for false detection conditions (based on sampling rate of 0.5 and 2 frames per second).

Alarm Method	0.5 frames per second		2 frames per second	
	Large number of false detections.	Typical number of false detections.	Large number of false detections.	Typical number of false detections.
Single Frame	4	2	5	2
3-pt Median	3	1	5	2
5-pt Median	3	1	4	1
7-pt Median	2	1	4	1
9-pt Median	2	1	4	1

Table 7: Maximum values of filters for pellet events (based on sampling rate of 0.5 and 2 frames per second).

Alarm Method	0.5 frames per second		2 frames per second	
	Burst pellet event.	Low intensity pellet event.	Burst pellet event.	Low intensity pellet event.
Single Frame	9	6	10	6
3-pt Median	7	5	9	5
5-pt Median	6	4	9	5
7-pt Median	6	4	8	5
9-pt Median	3	3	8	4

Table 8 shows the maximum values of the five alarm triggering methods attributed to false detections and the selected settings for triggering a pellet detection alarm for each sampling rate. Values for pellet alarm triggers were selected by considering the worst case scenario for false detections found in all of the available recorded videotapes. In actual practice, the 9-point median filter was not used for alarm triggering because it provided no additional performance improvement beyond the 7-point median filter (both the 7 and 9-point median filters triggered at value of 3 and the 9-point median filter required one additional sample to respond).

Table 8: Alarm settings based on a zero occurrence of false alarms (for a sampling rate of 2 and 0.5 frames per second).

Alarm Method	0.5 frames per second		2 frames per second	
	Maximum False Detection Signal	Selected Setting	Maximum False Detection Signal	Selected Setting
Single Image	6	7	7	6
3-point median	4	5	5	4
5-point median	3	4	5	4
7-point median	2	3	4	3
9-point median	2	3	4	3

5.4 Dynamic Validation

Table 9 shows the results of dynamic validation trials. Graphical results of the testing can be found in Appendix A.2. In the case of August 6, 1997, alarms did not trigger for a sampling rate of 0.5 frames per second. The footage was excluded from the analysis and is considered an example of where the system failed (a food pellet was on the lens and blocked the view). The average lag time between a hypothetical human observer sending a pellet loss alarm (based on 4 detectable pellets in an image, plus a 5 second reaction time) and the computer sending a pellet loss alarm was 1.1s for a sampling rate of 2 frames per second and 6.4s for a sampling rate of 0.5 frames per second. No apparent difference in lag time based on fish size or stocking density could be found. In general, a longer lag time to detection of uneaten food pellets resulted from a large number of fish feeding at the camera level and blocking the camera view.

Table 9: Average lag time (seconds) ± 95% confidence interval to a pellet alarm for the computer pellet detection system when compared to a hypothetical farm worker for different image sampling rates (n = 10).

Date	Sample	Stocking Density	2 frames per second	0.5 frames per second
July 12/01	A	Low	-1.2 ± 4.0	0.4 ± 2.8
July 12/01	B	Low	1.2 ± 3.5	5.0 ± 6.2
July 12/01	C	Low	-3.0 ± 4.8	0.4 ± 4.0
July 12/01	D	Low	-2.0 ± 4.8	2.0 ± 5.3
July 13/01	E	Low	-7.6 ± 5.1	-4.4 ± 7.9
Oct 10/94	F	Medium	6.5 ± 1.8	7.5 ± 2.0
Aug 5/97	G	Medium	21.3 ± 1.8	24.6 ± 1.8
July 11/01	H	Medium	-2.0 ± 1.5	14.8 ± 16.9
July 11/01	I	Medium	6.2 ± 1.8	8.2 ± 1.8
July 11/01	J	Medium	0.2 ± 10.1	11.0 ± 10.3
Aug 6/97	K	High	2.4 ± 6.4	N/A
Aug 8/97	L	High	3.8 ± 2.4	6.2 ± 5.7
Aug 9/97	M	High	-2.6 ± 8.8	-1.8 ± 6.4
June 27/00	N	High	2.0 ± 1.5	4.2 ± 4.2
June 27/00	O	High	-3.2 ± 0.9	13.4 ± 3.3
June 28/00	P	High	-3.4 ± 1.1	-1.8 ± 2.9
June 28/00	Q	High	-1.0 ± 2.2	1.4 ± 4.2
June 27/01	R	High	1.4 ± 16.9	7.2 ± 19.6
June 28/01	S	High	-0.8 ± 20.5	1.0 ± 4.6
June 28/01	T	High	3.4 ± 2.4	22.0 ± 23.8
Average	-	-	**1.1 ± 8.3**	**6.4 ± 13.2**

5.5 Field Observations

During the field trials, camera placement was found to be extremely important in ensuring that feed pellets pass through the camera view area. Because feeding fish will be located in the area with the highest amount of uneaten food pellets, centering the camera on the foraging fish was found to be most effective for locating uneaten food pellets (Figures 20 and 21 show examples of an off center camera). In Figure 21, pellet loss can be seen in the image, but the left third of the image consists of non-feeding fish against a background of the net. Figure 22 shows an off center camera where a large number of non-feeding fish are swimming through the camera view area. Figure 23 shows an example of a camera that is properly centered.

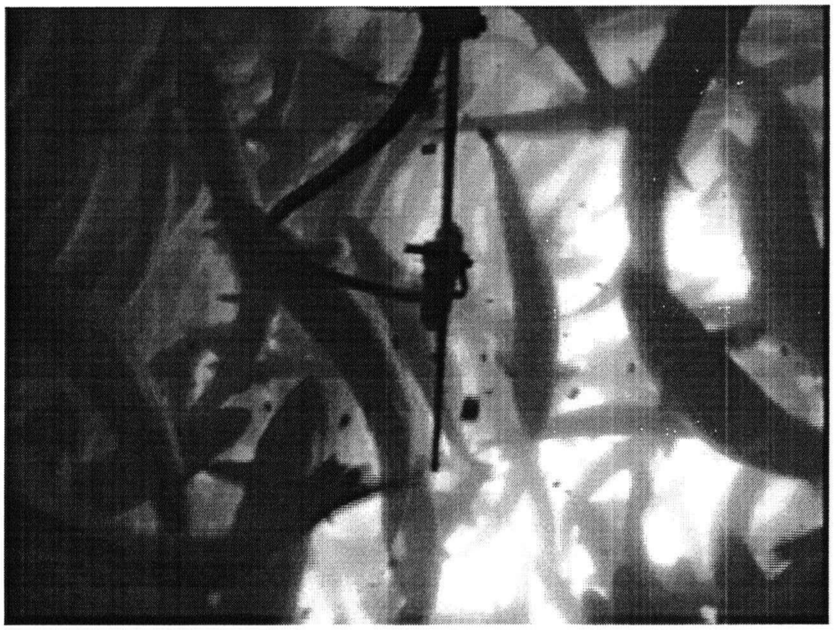


Figure 21: Example of an off center camera with pellet loss. Fish on the left are swimming beside the net.

A two-camera system was used in June and July, 2001, where one camera was placed near the water surface (usually 5m depth) and was used to ensure that the feed rate was appropriate and to assist in positioning the lower camera. The feed discharge rate was set so that a sustained, minimum number of pellets would be viewed in the top camera. When pellets became visible in the lower camera, the feed discharge rate was reduced.

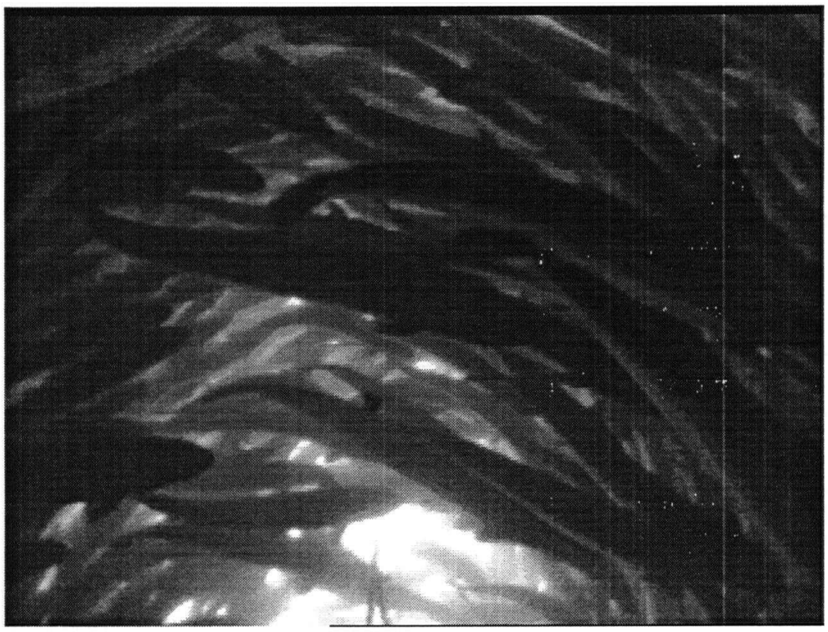


Figure 22: An example of an off center camera showing non-feeding fish. Fish are feeding in the bright area at the bottom of the image.

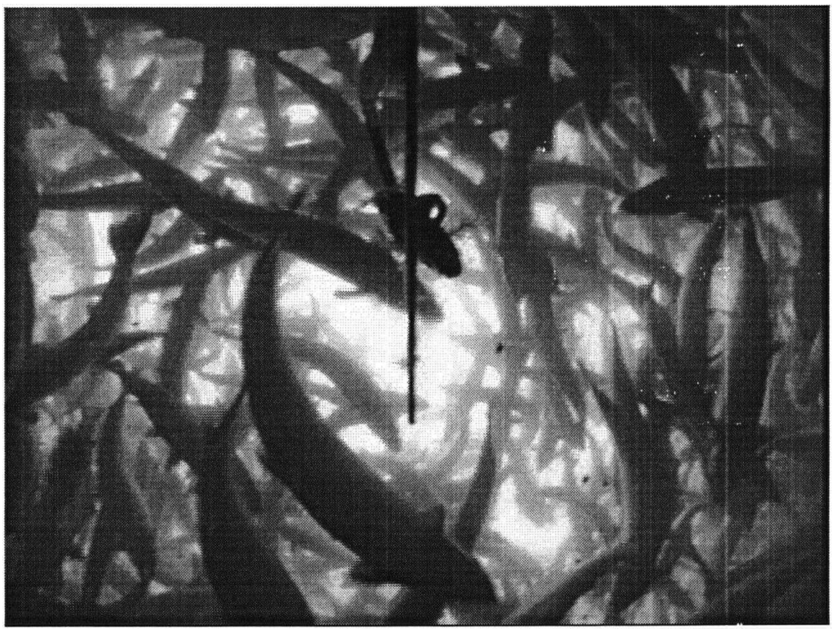


Figure 23: Example of a properly centered camera where fish are foraging directly above the camera.

Algal growth on the camera ropes increased the chances of generating a false pellet loss alarm. Figure 24 shows an example of where algal growth caused difficulties for the pellet detection system. In this case, food pellets became caught in the algae and were continually detected by the system. Other problems encountered in the field included bad camera connections, resulting in a very noisy image (Figure 25) and condensation on the camera lens (Figure 26), causing an image with reduced contrast. Condensation was found to clear up once the camera had a chance to warm up during operation.

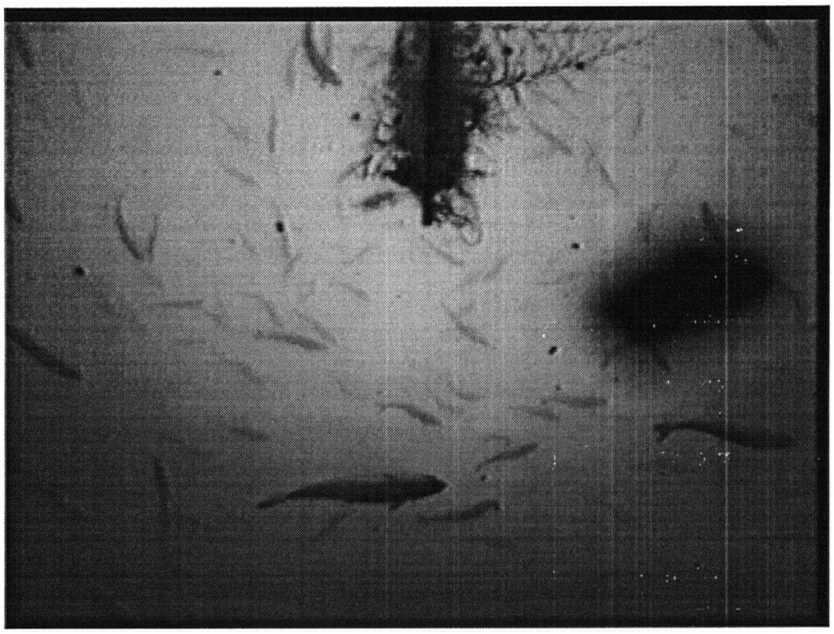


Figure 24: Example of algal growth on the camera rope, with food pellets caught in the algae.

During field trials a lighting system was used to indicate when a pellet detection alarm was triggered. Farm workers found them to be very useful and quickly relied on them as an indicator of pellet loss.

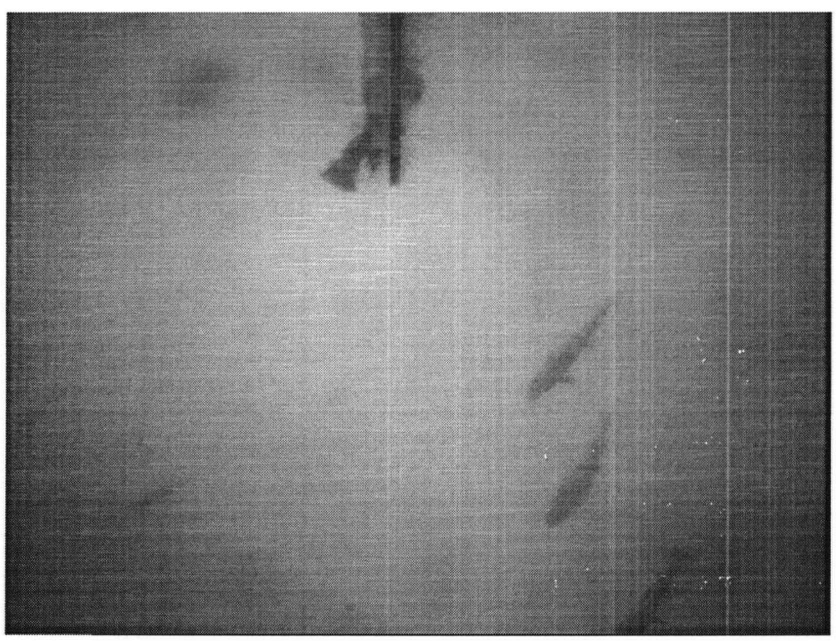


Figure 25: Example of a noisy image caused by a poor camera connection.

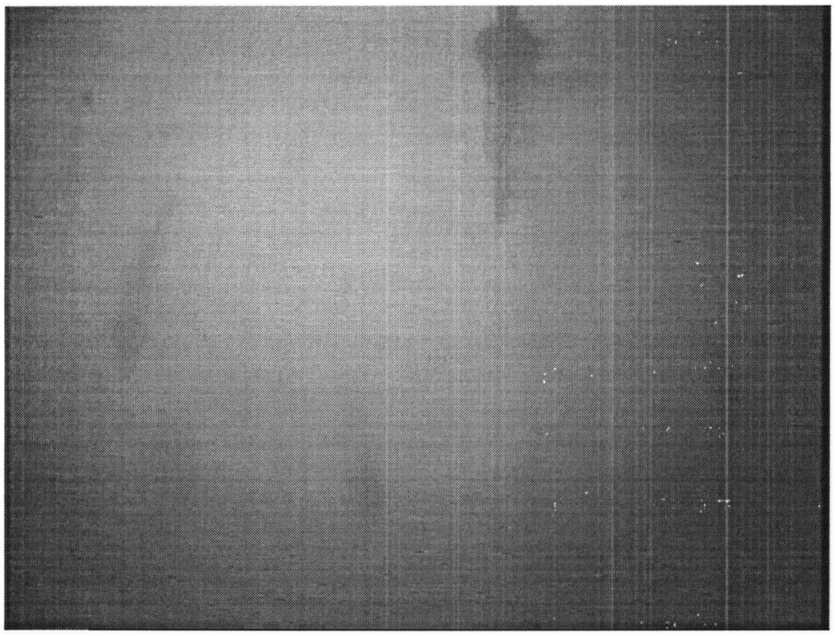


Figure 26: Example of a low contrast image caused by condensation on the camera lens.

6.0 Discussion and Application

6.1 Pellet Recognition Algorithm

6.1.1 Threshold step value (I_{STEP})

Choice of threshold step value used to segment objects from the image background had the following effects on the pellet recognition algorithm. Low values of the threshold step (1-3) resulted in a larger number of objects (pellet and non-pellet) being detected and an increase in processing time while higher values resulted in fewer objects being detected and a decreased image processing time. A threshold step value of 5 appeared to provide a good compromise between pellet detection and image processing time. It is conceivable that, with a faster computer system, it would be desirable to decrease the threshold step value to increase the pellet detection rate; however, false detections may also increase. A lower value of the threshold step may be particularly successful at detecting pellets, which are against a fish.

6.1.2 Feature descriptors

Selection of features to distinguish pellet and non-pellet objects was undertaken with three objectives: to maximize pellet detection, to minimize algorithm complexity and to minimize false detections.

Of the seven features that were tested (measured area, roughness, compactness, elongation, relative contrast, sinking speed and expected intensity), measured area, compactness, relative contrast and expected intensity were found most useful for pellet recognition and were used to discriminate food-pellets non-pellet objects. Sinking speed was rejected as a useful feature (although useful in theory) for two reasons. Firstly, it required that food pellets be tracked from frame to frame, which is difficult to do in practice because pellets in consecutive frames are often occluded by fish or disappear. Secondly, calculating sinking speed required two frames per camera to be captured and processed instead of just one, which halved the sampling speed.

The shape factors (roughness, compactness and elongation) were significantly correlated. The most likely reasons for the correlation were that: 1) the food pellets are very small and have little variation in shape (they tend to be circular) and 2) the three shape parameters all use features that are nearly the same in their calculation (measured area and perimeter). Compactness was used in the pellet recognition algorithm as its potential to separate pellets from non-pellets was higher and the others were closely related to it.

Pellet recognition features were not affected by actual food pellet size. This result was somewhat unexpected, particularly for the expected intensity as smaller pellets should appear somewhat darker than larger food pellets as they are closer to the camera at the same measured area. One reason for the lack of a trend could be that the overall image variability caused by fish stocking conditions, background lighting and the type of camera and lens were much greater than the variability caused by food pellet size.

6.2 Static Validation

Results for the static validation (single frame analysis) indicate that the pellet detection algorithm is effective under a broad range of salmon farming conditions. Food pellet diameter ranged from 2 – 11 mm, fish size from 0.025 – 4.8 kg, stocking density from 0.27 – 25.4 kg/m^3, camera depth from 4.5 – 20 m and water visibility from 3.5 – 10.5 m.

Based on the static validation results, the worst-case conditions for pellet detection is when a large number of fish are in the image. The primary reason for non-detection of pellets was because they were either on, or touching a fish (90% of missed pellets). This suggests that the main obstacle to having optimal pellet detection is the number of fish located in the image. According to section 3.1.1, fish tend to follow food pellets downward in the water column and non-feeding fish tend to accumulate near the perimeter and the cage bottom. Therefore, when the camera is positioned in an area where large number of fish are present (usually the cage bottom and sides), food pellets will be more difficult to detect. The camera may be placed mid-cage or the system may include computer code to indicate if too many fish (very dark images) are in front of the camera. As well, a device extending out from the camera to keep fish away from it could solve this problem.

The majority of false detections (non-pellets counted as pellets) were caused by the detection of waste matter (65% of the total number of false detections). In addition to the pellet classification algorithm, filters were implemented to remove false detections (Section 5.4).

A significant number of false detections (24% of the total number of false detections) were caused by the camera apparatus and were generally due to the growth of algae on the camera housing and rope. These false detections were termed avoidable because they could be eliminated by regularly cleaning the camera lens, cable and ropes.

6.3 Alarm Triggering and Sampling Speed

Results showed that it is not necessarily advantageous to increase the image sampling speed for the purpose of increasing the triggering of a pellet alarm. In some cases, increasing the sampling rate simply increased the detection of non-pellet objects (which sank more slowly than pellets). In the final detection algorithm, the number of pellets in a single image as well as the results from the 3, 5 and 7-point median filters were selected for alarm triggering.

The results from a longer filter (9-point median or greater) were not used as they did not provide for any performance enhancements over the shorter 7-point median filter. Theoretically, when using very long smoothing filters, their maximum value attributable to false detections will decrease until it equals the average value of false detections in the video footage (Vaseghi, 1996). During static validation, the average false detection rate was as high as 1.3, while the maximum value of the 7-point median filter caused by false detections was found to be 2 for a 0.5 frames per second sampling rate.

6.4 Dynamic Validation

The dynamic validation trials showed that when the pellet detection system was operated at a sampling rate of 0.5 frames per second, there was an average lag in response of 6.4 seconds between a hypothetical observer and the computer and at a sampling rate of 2 frames per second, the average lag in response was 1.1 seconds. When the sampling rate was decreased, the variability in the time for an alarm to trigger increased. Both sampling rates were within acceptable limits as set by the alarm triggering criteria.

6.6 Application

The pellet recognition system was found to accurately detect uneaten food pellets within a reasonable timeframe. In actual application, a number of conditions must be considered to ensure that the system operates in an effective manner.

1) The sampling rate per camera is maintained at a minimum of 0.5 frames per second.
2) The cameras are adequately maintained and properly functioning. Lenses, cables and ropes are cleaned at least once weekly during the summer months.
3) The cameras are centered below the foraging fish and within the sinking path of the food pellets. Also, the cameras must be kept away from the net walls and cage bottom where non-feeding fish prefer to reside.
4) At least 3 food pellets sized 30 pixels or greater are visible in any given image frame for 8 consecutive seconds (0.5 frames per second sampling rate). At least 4 food pellets sized 30 pixels or greater are visible in any given image frame for 2 consecutive seconds (2 frames per second sampling rate).
5) To eliminate the time lag in the computer sending a pellet alarm as compared to a human, the camera should be positioned slightly higher in the cage than normal.

Once a sufficient number of food pellets have been detected to trigger an alarm, the computer is capable of sending a control signal. This signal can be used to trigger an alarm light (used during field trials), sounding device or control a feeder. Based on the required sampling rate of 0.5 frames per second, the maximum number of cameras that could be monitored simultaneously when using the test (0.95 GHz) computer system was four. The use of a faster computer system would increase the number of cameras that could be sampled from.

The pellet recognition system does not need calibration to be functional. It is anticipated that a field version would also have the ability to keep records of feeding for each cage. A farm worker could simply use the system to indicate pellet loss (i.e. alarm lights) or it could be developed into a complete feed control system.

7.0 Conclusions and Recommendations

A method for detecting uneaten food pellets in high clutter underwater images with variable background and lighting conditions was developed. Development and testing of the pellet recognition algorithm was completed using images representing a wide range of environmental and fish stocking conditions found in netcage aquaculture. The range of testing conditions were:

- Food pellet diameter: 2 to 11mm.
- Water visibility: 3.5 – 11m (measured using a secchi disk at 2:00 pm).
- Fish size: 0.025 – 4.8 kg.
- Fish stocking density ranged 0.27 – 20.3 kg/m^3.

As a first step to developing the pellet recognition program, a pellet detection algorithm was developed to distinguish between pellet and non-pellet objects. Based on single frame validation, the pellet recognition algorithm was capable of detecting an average of 84% of all food pellets sized 30 pixels or greater. The average false detection rate was 0.57 per frame.

Using the pellet detection algorithm, a program was developed to detect pellet loss in live videos of feeding events. Filters were used to suppress false detections and the threshold to trigger a pellet detection alarm was set to ensure a zero occurrence of false alarms. With these alarm trigger settings, the following minimum amount of pellet loss was necessary to trigger a pellet detection alarm: at least 3 food pellets sized 30 pixels or greater are visible in any given image frame for 8 consecutive seconds (0.5 frames per second sampling rate), or at least 4 food pellets sized 30 pixels or greater are visible in any given image frame for 2 consecutive seconds (2 frames per second sampling rate).

Testing of the final pellet detection program on videos of actual pellet loss events showed that the program was effective in detecting pellet loss events as long as the following conditions were met: 1) cameras were positioned within the sinking path of the food pellets. 2) cameras were positioned away from the areas where non-feeding fish congregated (cage sides and bottom).

Additional work is necessary to develop an automated fish-feeding system based on the pellet detection program. Future work should focus on the following areas:

1) The addition of fish-feeder controls to the system.
2) Developing computer algorithms to detect system failures (i.e. poor video connection, improper camera position, feeder malfunction).
3) Long-term feeding trials to assess the effectiveness of the pellet detection system in controlling feeding.

8.0 References

Alanara, A., 1992. The Effect of Time-Restricted Demand Feeding on Feeding Activity, Growth and Feed Conversion in Rainbow Trout (*Oncorhynchus mykiss*). Aquaculture, 108, 357-368.

Ang, K. and Petrell, R., 1997. Control of Feed Dispensation in Seacages Using Underwtaer Video Monitoring: Effects on Growth and Feed Conversion. Aquacultural Engineering, 16, 45-62.

Ang, K. and Petrell, R., 1998. Pellet Wastage, and Subsurface and Surface Feeding Behaviours Associated with Different Feeding Systems in Sea Cage Farming of Salmonids. Aquacultural Engineering, 18, 95-115.

Baldock, R. and Graham, J., 2000. Image Processing and Analysis. New York: Oxford University Press, 301pp.

B.C. Salmon Farmers Association., 1999. Salmon Farming in B.C.: Eceonomic Benefits and Production. http://www.bcsalmonfarms.bc.ca/netwrok/quick%20facts%201.htm

Bjorklund, H., Bondestam, J. and Bylund, G., 1990. Residues of Oxytetracycline in Wild Fish and Sediments from Fish Farms. Aquaculture. 86, 359-367.

Blyth, P., Purser, G., and Russell, J., 1993. Detection of Feeding Rhythms in Seacaged Atlantic Salmon Using New Feeder Technology. In: Reinertsen, Dahle, Jorgensen and Tvinnereim (Eds.) Fish Farming Technology, Balkema, Rotterdam, 1993, 209-216.

Boucher, E. and Petrell, R., 1999. Swimming Speed and Morphological Features of Mixed Populations of Early maturing and Non-Maturing Fish. Aquacultural Engineering, 20, 21-35.

Brandtburg, T. and Walter, F., 1998. Automated Delineation of Individual Tree Crowns in High Spatial Resolution Aerial Images by Multiple-Scale Analysis. Machine Vision and Applications, 11, 64-73.

Drouin, M., 1998. Can Salmon Farmers Keep Their Price Edge? Pacific Fishing, 19, 32-33.

Foster, M., 1993. An Automated Vision System for Detection Counting of Uneaten Food Pellets in a Fish Sea Cage. Masters Thesis – Department of Electrical Engineering – The University of British Columbia.

Foster, M., Petrell, R., Ito, M., and Ward, R., 1995. Detection and Counting of Uneaten Food Pellets in a Sea Cage Using Image Analysis. Aquacultural Engineering, 14(3), 251-269.

Guthrie, D. and Muntz, W., 1993. Role of Vision in Fish Behaviour. In: Pitcher, T. (Ed.) Behaviour of Teleost Fishes 2nd Edition. Chapman and Hall, pp 89-128.

Jorgensen, E. and Jobling, M., 1992. Feeding Behaviour and Effect of Feeding Regime on Growth of Atlantic Salmon, *Salmo Salar*. Aquaculture, 101, 135-146.

Juell, J., Furevik, D. and Bjordal, A., 1993. Demand Feeding in Salmon Farming by Hydroacoustic Food Detection. Aquacultural Engineering, 12, 155-167.

Kadri, S., Huntingford, F., Metcalfe, N. and Thorpe, J., 1996. Social Interactions and the Distribution of Food Among One-Sea-Winter Atlantic Salmon (*Salmo salar*) in a Sea-Cage. Aquaculture, 139, 1-10.

Keshavmurthy, S., Goodsitt, M., Chan H. and Helvie, M., 1999. Design and Evaluation of an External Filter for Exposure Equalization in Mammography. Medical Physics, 26(8), 1655-1661.

Ko, S. and Lee, Y., 1991. Center Weighted Median Filters and Their Applications to Image Enhancement. IEEE Transactions on Circuits and Systems. 38(9), 984-993.

Metcalfe, N., 1994. The Role of Behaviour in Determining Salmon Growth and Development. Aquaculture and Fisheries Management. 25, 67-76.

Palowitch, A. and Jaffe, S., 1991. Computer Model for Predicting Underwater Color Images. In: Spinrad, R. (Ed.), Underwater Imaging Photography, and Visibility. Proceedings of the International Society for Optical Engineering, 21 – 26 July, 1991, Bellingham, WA, pp. 128 – 139.

Patton, W. and Tempst, P., 1993. Enhancing Spot Detection and Reducing Noise From Digitized Electrophoretic Gel Images Using Area ProcessingFilters. Electrophoresis, 14, 650-658.

Petrell, R. and Ang, K., 2001. Effects of Pellet Contrast and Light Intensity on Salmonid Feeding Behaviours. In Press.

Shieh, A. and Petrell, R., 1998. Measurements of Fish Size in Atlantic Salmon (*Salmo Salar L.*) Cages Using Stereographic Video Techniques. Aquacultural Engineering, 17, 29-43.

Thorpe, J., Talbot, C., Miles, M., Rawlings, C. and Keay, D., 1990. Food Consumption in 24 Hours by Atlantic Salmon (*Salmo salar L.*) in a Sea Cage. Aquaculture, 90, 41-47.

Vaseghi, S., 1996. Advanced Signal Processing and Digital Noise Reduction. New York: Wiley and Teubner, 397 pp.

Wong, K. and Piedrahita, R., 2000. Settling Velocity Characterization of Aquacultural Solids. Aquacultural Engineering, 21, 233-246.

Appendix A.1

Static Validation

Date: July 29, 1994 Time: 10:30AM Weather: Overcast Camera Depth: 8m Light Intensity: 800 $\mu E/m^2/s$ Water Visibility: 4m
Fish Size: 4.3kg Stocking Density: $5.6kg/m^3$ Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:00:04:26	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
002	0:00:06:01	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
003	0:00:08:16	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
004	0:00:09:26	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
005	0:00:11:06	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
006	0:00:12:13	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fish
				Both	0	0	1	—	Fish
007	0:00:17:04	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:00:25:06	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
009	0:00:26:17	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	1	—	Fecal

Date: July 29, 1994 Time: 10:30AM Weather: Overcast Camera Depth: 8m Light Intensity: 800 $\mu E/m^2/s$ Water Visibility: 4m
Fish Size: 4.3kg Stocking Density: 5.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:00:27:21	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
011	0:00:30:02	During feeding, dark, few fish near camera.	0	Odd	0	0	3	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	3	—	Fecal
012	0:00:31:12	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
013	0:00:35:00	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
014	0:00:39:19	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
015	0:00:41:28	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	3	—	Fecal
016	0:00:43:09	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
017	0:00:44:12	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
018	0:00:46:25	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	3	—	Fecal

Date: July 29, 1994 Time: 10:30AM Weather: Overcast Camera Depth: 8m Light Intensity: 800 $\mu E/m^2/s$ Water Visibility: 4m
Fish Size: 4.3kg Stocking Density: 5.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:00:50:19	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
020	0:00:52:22	During feeding, dark, few fish near camera.	0	Odd	0	0	3	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	3	—	Fecal
021	0:00:55:10	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
022	0:00:56:18	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
023	0:00:58:29	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
024	0:01:00:06	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
025	0:1:01:16	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
026	0:01:04:02	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
027	0:01:07:17	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 29, 1994 Time: 10:30AM Weather: Overcast Camera Depth: 8m Light Intensity: 800 $\mu E/m^2/s$ Water Visibility: 4m
Fish Size: 4.3kg Stocking Density: 5.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:01:10:05	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
029	0:01:15:24	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
030	0:01:17:01	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Fecal, Fish
				Both	0	0	2	—	Fecal, Fish
031	0:01:20:17	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	4	—	Fecal
032	0:01:22:00	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
033	0:01:23:06	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
034	0:01:24:12	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
035	0:01:29:03	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
036	0:01:31:14	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal

Date: July 29, 1994 Time: 10:30AM Weather: Overcast Camera Depth: 8m Light Intensity: 800 $\mu E/m^2/s$ Water Visibility: 4m
Fish Size: 4.3kg Stocking Density: 5.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:01:39:10	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	3	—	Fecal
038	0:01:46:02	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
039	0:01:47:08	During feeding, dark, few fish near camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
040	0:01:48:17	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
041	0:01:50:26	During feeding, dark, few fish near camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
042	0:01:52:04	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
043	0:01:53:14	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
044	0:01:54:19	During feeding, dark, few fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: October 10, 1994 Time: 8:30AM Weather: Sunny With Clouds Camera Depth: 8m Light Intensity: 900 $\mu E/m^2/s$ Water Visibility: 8m
Fish Size: 2.1kg Stocking Density: $6.8kg/m^3$ Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Missed	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	1:08:54:06	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
002	1:08:56:19	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
003	1:09:01:05	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
004	1:09:04:22	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
005	1:09:06:02	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
006	1:09:08:18	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
007	1:09:09:24	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	1:09:12:10	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
009	1:09:14:23	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: October 10, 1994 Time: 8:30AM Weather: Sunny With Clouds Camera Depth: 8m Light Intensity: 900 $\mu E/m^2/s$ Water Visibility: 8m
Fish Size: 2.1kg Stocking Density: $6.8kg/m^3$ Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	1:09:16:00	During feeding, few fish near camera, medium brightness.	1	Odd	1	0	0	—	—
				Even	0	1	0	Shape	—
				Both	1	0	0	—	—
011	1:09:17:12	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
012	1:09:18:24	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	1	1	0	Shape	—
				Both	2	0	0	—	—
013	1:09:20:03	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
014	1:09:21:12	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	2	0	1	—	Fish
				Both	2	0	1	—	Fish
015	1:09:22:27	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
016	1:09:24:07	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
017	1:09:25:17	During feeding, few fish near camera, medium brightness.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
018	1:09:27:00	During feeding, few fish near camera, medium brightness.	5	Odd	3	2	1	Shape, On Fish	Fish
				Even	3	2	1	Shape, On Fish	Fish
				Both	5	1	1	On Fish	Fish

Date: October 10, 1994 Time: 8:30AM Weather: Sunny With Clouds Camera Depth: 8m Light Intensity: 900 $\mu E/m^2/s$ Water Visibility: 8m
Fish Size: 2.1kg Stocking Density: $6.8 kg/m^3$ Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	1:09:28:12	During feeding, few fish near camera, medium brightness.	5	Odd	5	0	0	—	—
				Even	5	0	0	—	—
				Both	5	0	0	—	—
020	1:09:29:25	During feeding, few fish near camera, medium brightness.	7	Odd	6	1	0	On Fish	—
				Even	4	3	0	On Fish	—
				Both	6	1	0	On Fish	—
021	1:09:31:08	During feeding, few fish near camera, medium brightness.	5	Odd	3	2	0	Shape	—
				Even	4	1	0	Shape	—
				Both	5	0	0	—	—
022	1:09:32:18	During feeding, few fish near camera, medium brightness.	4	Odd	4	0	0	—	—
				Even	4	0	0	—	—
				Both	4	0	0	—	—
023	1:09:33:28	During feeding, few fish near camera, medium brightness.	6	Odd	4	2	0	On Fish	—
				Even	5	1	1	Shape	Fish
				Both	6	0	1	—	Fish
024	1:09:35:11	During feeding, few fish near camera, medium brightness.	4	Odd	4	0	0	—	—
				Even	3	1	0	On Fish	—
				Both	4	0	0	—	—
025	1:09:36:23	During feeding, few fish near camera, medium brightness.	7	Odd	5	2	0	On Fish	—
				Even	4	3	1	On Fish	Fish
				Both	6	1	1	On Fish	Fish
026	1:09:38:04	During feeding, few fish near camera, medium brightness.	10	Odd	6	4	0	On Fish	—
				Even	7	3	0	2 On Fish, 1 Shape	—
				Both	9	1	0	On Fish	—
027	1:09:39:11	During feeding, few fish near camera, medium brightness.	6	Odd	5	1	0	On Fish	—
				Even	6	0	0	—	—
				Both	6	0	0	—	—

Date: October 10, 1994 Time: 8:30AM Weather: Sunny With Clouds Camera Depth: 8m Light Intensity: 900 $\mu E/m^2/s$ Water Visibility: 8m
Fish Size: 2.1kg Stocking Density: $6.8 kg/m^3$ Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	1:09:40:24	During feeding, few fish near camera, medium brightness.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
029	1:09:42:02	During feeding, few fish near camera, medium brightness.	4	Odd	3	1	1	Shape	Fish
				Even	4	0	0	—	—
				Both	4	0	1	—	Fish
030	1:09:43:11	During feeding, few fish near camera, medium brightness.	2	Odd	2	0	0	—	—
				Even	1	1	1	On Fish	Fecal
				Both	2	0	1	—	Fecal
031	1:09:44:23	During feeding, few fish near camera, medium brightness.	5	Odd	3	2	0	On Fish	—
				Even	4	1	0	On Fish	—
				Both	5	0	0	—	—
032	1:09:45:29	During feeding, few fish near camera, medium brightness.	7	Odd	5	2	0	On Fish	—
				Even	6	1	0	On Fish	—
				Both	7	0	0	—	—
033	1:09:47:09	During feeding, few fish near camera, medium brightness.	8	Odd	6	2	0	On Fish	—
				Even	7	1	1	Shape	Fish
				Both	8	0	1	—	Fish
034	1:09:48:24	During feeding, few fish near camera, medium brightness.	9	Odd	7	2	0	On Fish	—
				Even	8	1	0	On Fish	—
				Both	8	1	0	On Fish	—
035	1:09:50:06	During feeding, few fish near camera, medium brightness.	9	Odd	6	3	0	1 On Fish, 2 Shape	—
				Even	6	3	1	On Fish	Fish
				Both	8	1	1	On Fish	Fish
036	1:09:51:19	During feeding, few fish near camera, medium brightness.	6	Odd	3	3	1	On Fish	Fish
				Even	3	3	1	2 On Fish, 1 Shape	Fish
				Both	4	2	1	On Fish	Fish

Date: October 10, 1994 Time: 8:30AM Weather: Sunny With Clouds Camera Depth: 8m Light Intensity: 900 $\mu E/m^2/s$ Water Visibility: 8m
Fish Size: 2.1kg Stocking Density: 6.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	1:09:52:28	During feeding, few fish near camera, medium brightness.	5	Odd	5	0	0	—	—
				Even	3	2	0	On Fish	—
				Both	5	0	0	—	—
038	1:09:54:11	During feeding, few fish near camera, medium brightness.	6	Odd	6	0	0	—	—
				Even	4	2	0	Shape	—
				Both	6	0	0	—	—
039	1:09:55:23	During feeding, few fish near camera, medium brightness.	4	Odd	3	1	0	On Fish	—
				Even	3	1	0	On Fish	—
				Both	3	1	0	On Fish	—
040	1:09:57:05	During feeding, few fish near camera, medium brightness.	9	Odd	5	4	1	2 On Fish, 2 Shape	Fish
				Even	9	0	1	—	Fish
				Both	9	0	1	—	Fish
041	1:09:58:16	During feeding, few fish near camera, medium brightness.	10	Odd	9	1	0	On Fish	—
				Even	9	1	0	Shape	—
				Both	10	0	0	—	—
042	1:10:00:00	During feeding, few fish near camera, medium brightness.	6	Odd	5	1	0	Shape	—
				Even	6	0	0	—	—
				Both	6	0	0	—	—
043	1:10:01:09	During feeding, few fish near camera, medium brightness.	6	Odd	5	1	1	Shape	Fish
				Even	4	2	1	On Fish, Shape	Fish
				Both	6	0	2	—	Fish
044	1:10:02:20	During feeding, few fish near camera, medium brightness.	5	Odd	2	3	0	1 On Fish, 2 Shape	—
				Even	4	1	0	On Fish	—
				Both	4	1	0	On Fish	—

Date: August 5, 1997 Time: 5:00PM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.3kg Stocking Density: $6.2kg/m^3$ Pellet Size: 6.5-8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:02:12:04	Start of feeding, fish are foraging, some near camera	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
002	0:02:28:16	Pellet loss, lots of fish near camera.	1	Odd	0	1	1	On Fish	Fecal
				Even	1	0	0	—	—
				Both	1	0	1	—	Fecal
003	0:02:30:00	Pellet loss, lots of fish near camera.	1	Odd	1	0	1	—	Fecal
				Even	1	0	1	—	Fecal
				Both	1	0	1	—	Fecal
004	0:02:43:07	Pellet loss, lots of fish near camera.	3	Odd	2	1	0	On Fish	—
				Even	2	1	0	On Fish	—
				Both	2	1	0	On Fish	—
005	0:02:49:12	Pellet loss, lots of fish near camera.	2	Odd	2	0	1	—	Fecal
				Even	1	1	2	On Fish	Fecal
				Both	2	0	2	—	Fecal
006	0:02:50:25	Pellet loss, lots of fish near camera.	4	Odd	4	0	1	—	Fecal
				Even	3	1	1	On Fish	Fecal
				Both	4	0	1	—	Fecal
007	0:02:59:20	Pellet loss, lots of fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:03:03:26	Pellet loss, lots of fish near camera.	6	Odd	5	1	1	On Fish	Fecal
				Even	3	3	1	2 On Fish, 1 Shape	Fecal
				Both	5	1	1	On Fish	Fecal
009	0:03:05:14	Pellet loss, lots of fish near camera.	3	Odd	2	1	0	On Fish	—
				Even	1	2	0	On Fish	—
				Both	2	1	0	On Fish	—

Date: August 5, 1997 Time: 5:00PM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.3kg Stocking Density: 6.2kg/m^3 Pellet Size: 6.5-8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:03:06:25	Pellet loss, lots of fish near camera.	3	Odd	0	3	1	2 On Fish, 1 Shape	Fish
				Even	1	2	0	On Fish, Shape	—
				Both	1	2	1	On Fish, Shape	Fish
011	0:03:12:07	Pellet loss, lots of fish near camera.	2	Odd	2	0	0	—	—
				Even	1	1	0	On Fish	—
				Both	2	0	0	—	—
012	0:03:13:22	Pellet loss, lots of fish near camera.	3	Odd	2	1	0	On Fish	—
				Even	2	1	0	On Fish	—
				Both	2	1	0	On Fish	—
013	0:03:16:14	Pellet loss, lots of fish near camera.	4	Odd	2	2	0	Shape	—
				Even	4	0	1	—	Fish
				Both	4	0	1	—	Fish
014	0:03:21:28	Pellet loss, lots of fish near camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
015	0:03:24:16	Fish foraging near camera, no foraging at water surface.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
016	0:03:25:27	Fish foraging near camera, no foraging at water surface.	4	Odd	0	4	0	On Fish	—
				Even	3	1	0	On Fish	—
				Both	3	1	0	On Fish	—
017	0:03:27:07	Fish foraging near camera, no foraging at water surface.	10	Odd	8	2	0	On Fish	—
				Even	8	2	0	On Fish	—
				Both	8	2	0	On Fish	—
018	0:03:28:23	Fish foraging near camera, no foraging at water surface.	4	Odd	4	0	1	—	Fecal
				Even	3	1	0	On Fish	—
				Both	4	0	1	—	Fecal

Date: August 5, 1997 Time: 5:00PM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.3kg Stocking Density: 6.2kg/m^3 Pellet Size: 6.5-8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:03:32:22	Fish foraging near camera, no foraging at water surface.	2	Odd	2	0	1	—	Fecal
				Even	2	0	0	—	—
				Both	2	0	1	—	Fecal
020	0:03:34:05	End of feeding, some fish still near camera.	0	Odd	0	0	2	—	Fecal, Fish
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal, Fish
021	0:03:44:16	End of feeding, no fish in center of cage.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
022	0:03:46:12	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
023	0:03:48:22	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
024	0:03:52:24	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
025	0:03:55:16	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
026	0:03:57:02	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
027	0:03:58:10	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal

Date: August 5, 1997 Time: 5:00PM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.3kg Stocking Density: 6.2kg/m^3 Pellet Size: 6.5-8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:04:01:04	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
029	0:04:02:30	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	Fecal
				Both	0	0	1	—	Fecal
030	0:04:04:07	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
031	0:04:05:16	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
032	0:04:09:18	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
033	0:04:11:04	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
034	0:04:12:17	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
035	0:04:14:03	End of feeding, no fish in center of cage.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
036	0:04:15:18	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: August 5, 1997 Time: 5:00PM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.3kg Stocking Density: 6.2kg/m^3 Pellet Size: 6.5-8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:04:17:01	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
038	0:04:18:18	End of feeding, no fish in center of cage.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
039	0:04:20:01	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
040	0:04:25:21	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
041	0:04:27:05	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
042	0:04:28:18	End of feeding, no fish in center of cage.	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
043	0:04:30:03	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
044	0:04:31:28	End of feeding, no fish in center of cage.	0	Odd	0	0	0	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal

Date: August 6, 1997 Time: 9:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:07:11:21	Light foraging Fish near camera	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
002	0:07:15:29	Start of feeding Heavy foraging Fish near camera	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
003	0:07:23:24	Heavy foraging Fish at middle depth	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
004	0:07:25:05	Heavy foraging Fish at middle depth	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
005	0:07:26:17	Heavy foraging Fish at middle depth	6	Odd	3	2	0	On Fish	—
				Even	4	1	0	On Fish	—
				Both	5	1	0	On Fish	—
006	0:07:28:00	Heavy foraging Fish at middle depth	1	Odd	0	1	1	On Fish	Fish
				Even	0	1	0	On Fish	—
				Both	0	1	1	On Fish	Fish
007	0:07:29:12	Heavy foraging Fish at middle depth	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
008	0:07:30:26	Heavy foraging Fish at middle depth	4	Odd	4	0	0	—	—
				Even	4	0	0	—	—
				Both	4	0	0	—	—
009	0:07:32:08	Heavy foraging Fish at middle depth	7	Odd	3	4	1	On Fish	Fish
				Even	1	6	1	On Fish	Fish
				Both	3	4	1	On Fish	Fish

Date: August 6, 1997 Time: 9:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:07:33:22	Heavy foraging Fish at middle depth	5	Odd	4	1	0	On Fish	—
				Even	3	2	0	On Fish	—
				Both	5	0	0	—	—
011	0:07:35:04	Heavy foraging Fish at middle depth Heavy pellet loss	9	Odd	2	7	0	On Fish	—
				Even	4	5	0	On Fish	—
				Both	5	4	0	On Fish	—
012	0:07:38:01	Heavy foraging Fish closer to camera	3	Odd	3	0	1	—	Fecal
				Even	2	1	1	Shape	Fecal
				Both	3	0	2	—	Fecal
013	0:07:39:16	Heavy foraging Fish closer to camera	5	Odd	3	2	0	On Fish	—
				Even	4	1	0	On Fish	—
				Both	5	0	0	—	—
014	0:07:41:29	Heavy foraging Fish closer to camera	2	Odd	0	2	0	On Fish	—
				Even	0	2	0	On Fish	—
				Both	0	2	0	On Fish	—
015	0:07:43:06	Heavy foraging Fish near camera	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
016	0:07:47:28	Foraging Fish near camera	3	Odd	3	0	0	—	—
				Even	2	1	0	On Fish	—
				Both	3	0	0	—	—
017	0:07:50:10	Foraging Fish near camera	5	Odd	3	2	0	On Fish, Shape	—
				Even	3	2	0	On Fish, Shape	—
				Both	5	0	0	—	—
018	0:07:51:24	Foraging Fish near camera	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—

Date: August 6, 1997 Time: 9:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:07:54:15	Foraging Fish near camera	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
020	0:07:56:07	Foraging Fish near camera	4	Odd	2	2	0	On Fish	—
				Even	2	2	0	On Fish	—
				Both	2	2	0	On Fish	—
021	0:07:57:26	Foraging Fish near camera	4	Odd	3	1	0	On Fish	—
				Even	4	0	0	—	—
				Both	4	0	0	—	—
022	0:07:59:14	Foraging Fish near camera	1	Odd	0	1	1	On Fish	Fecal
				Even	0	1	1	On Fish	Fecal
				Both	0	1	1	On Fish	Fecal
023	0:08:01:02	Foraging Fish near camera	7	Odd	5	2	1	On Fish	Fish
				Even	3	3	0	On Fish	—
				Both	6	1	1	On Fish	Fish
024	0:08:02:16	Foraging Fish near camera	3	Odd	2	1	0	On Fish	—
				Even	0	3	0	2 On Fish, 1 Shape	—
				Both	2	1	0	On Fish	—
025	0:08:12:29	Very light foraging End of feeding	0	Odd	0	0	2	—	Fecal, Fish
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal, Fish
026	0:08:14:14	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
027	0:08:15:29	Very light foraging	0	Odd	0	0	2	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	3	—	Fecal

Date: August 6, 1997 Time: 9:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:08:17:17	Very light foraging	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
029	0:08:19:04	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
030	0:08:22:05	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
031	0:08:28:01	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
032	0:08:29:16	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
033	0:08:31:02	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
034	0:08:33:26	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
035	0:08:35:12	Very light foraging	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
036	0:08:36:25	Fish returning to formation	0	Odd	0	0	2	—	Fecal, Fish
				Even	0	0	1	—	Fecal
				Both	0	0	3	—	2 Fecal, 1 Fish

Date: August 6, 1997 Time: 9:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 3.5m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	0	—	—
037	0:08:39:21	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
038	0:08:41:07	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	1	—	Fecal
039	0:08:45:19	Fish swimming	0	Even	0	0	1	—	Fish
				Both	0	0	2	—	Fecal, Fish
				Odd	0	0	0	—	—
040	0:08:47:07	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
041	0:08:48:25	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
042	0:08:56:17	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
043	0:08:58:00	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
044	0:08:59:21	Fish swimming	0	Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: August 7, 1997 Time: 10:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 6.0m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:00:14:29	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
002	0:00:21:02	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
003	0:00:35:24	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
004	0:00:51:02	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	2	—	Fecal, Fish
				Even	0	0	2	—	Fecal, Fish
				Both	0	0	2	—	Fecal, Fish
005	0:01:15:11	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Fecal, Fish
				Both	0	0	2	—	Fecal, Fish
006	0:01:54:19	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
007	0:02:01:03	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:02:22:12	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
009	0:02:26:12	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: August 7, 1997 Time: 10:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 6.0m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:02:30:02	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
011	0:02:34:23	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
012	0:02:39:17	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
013	0:02:46:20	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
014	0:03:08:04	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	5	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	5	—	Fecal
015	0:03:09:20	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	5	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	5	—	Fecal
016	0:03:12:06	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
017	0:03:16:09	Before feeding, fish near image edge, no fish in image center.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
018	0:04:42:12	Start of feeding, foraging at water surface.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: August 7, 1997 Time: 10:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 6.0m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:08:15:27	Fish feeding over camera, midway to camera level.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
020	0:08:55:19	Fish feeding just above camera, heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
021	0:09:27:08	Fish feeding at camera level, heavy foraging.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fish
				Both	0	0	2	—	Fecal, Fish
022	0:09:43:11	Fish feeding at camera level, heavy foraging.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
023	0:09:55:09	Fish feeding at camera level, heavy foraging.	5	Odd	2	3	2	On Fish	Fecal
				Even	4	1	2	On Fish	Fecal
				Both	4	1	2	On Fish	Fecal
024	0:09:57:15	Fish feeding at camera level, heavy foraging.	1	Odd	1	0	2	—	Camera, Fecal
				Even	1	0	1	—	Fecal
				Both	1	0	3	—	1 Camera, 2 Fecal
025	0:10:14:21	Fish moving up, light foraging.	0	Odd	0	0	3	—	1 Camera, 2 Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	4	—	1 Camera, 3 Fecal
026	0:10:16:02	No feeding activity, no fish over camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	3	—	Fecal
027	0:10:17:14	No feeding activity, no fish over camera.	0	Odd	0	0	3	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	4	—	Fecal

Date: August 7, 1997 Time: 10:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 6.0m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:10:18:29	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
029	0:10:21:15	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
030	0:10:22:25	No feeding activity, no fish over camera.	0	Odd	0	0	3	—	1 Camera, 2 Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	6	—	1 Camera, 5 Fecal
031	0:10:35:17	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Camera
				Both	0	0	1	—	Camera
032	0:10:37:27	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
033	0:10:41:12	No feeding activity, no fish over camera.	0	Odd	0	0	1	—	Fish
				Even	0	0	1	—	Fish
				Both	0	0	2	—	Fish
028	0:10:18:29	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
034	0:10:43:29	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	2	—	Fish, Fecal
				Both	0	0	2	—	Fish, Fecal
035	0:11:07:28	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: August 7, 1997 Time: 10:00AM Weather: Sunny Camera Depth: 14m Light Intensity: Unknown Water Visibility: 6.0m
Fish Size: 2.8kg Stocking Density: 11.0kg/m^3 Pellet Size: 8.5mm Cage Size: 12m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
036	0:11:15:08	No feeding activity, no fish over camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
037	0:11:16:19	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
038	0:11:18:01	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
039	0:11:34:06	No feeding activity, no fish over camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
040	0:11:45:01	No feeding activity, no fish over camera.	0	Odd	0	0	3	—	1 Camera, 2 Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	4	—	1 Camera, 3 Fecal
041	0:11:46:09	No feeding activity, no fish over camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
042	0:11:47:17	No feeding activity, no fish over camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
043	0:11:51:09	No feeding activity, no fish over camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
044	0:11:57:05	No feeding activity, no fish over camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Camera, Fecal
				Both	0	0	2	—	Camera, Fecal

Date: June 27,2000 Time: 8:00AM Weather: Sunny Camera Depth: 12-23m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 4.8kg Stocking Density: 7.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:05:27:13	Heavy foraging activity, fish near camera.	1	Odd	1	0	1	—	Fecal
				Even	1	0	1	—	Fecal
				Both	1	0	1	—	Fecal
002	0:05:33:09	Heavy foraging activity, fish near camera	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
003	0:05:43:02	Heavy foraging activity, fish near camera	4	Odd	2	2	1	On Fish	Fecal
				Even	2	2	0	On Fish	—
				Both	3	1	1	On Fish	Fecal
004	0:05:45:18	Heavy foraging activity, fish near camera	6	Odd	4	2	0	On Fish	—
				Even	4	2	0	On Fish	—
				Both	5	1	0	On Fish	—
005	0:05:48:04	Heavy foraging activity, fish near camera	5	Odd	4	1	1	On Fish	Fecal
				Even	5	0	2	—	Fecal
				Both	5	0	2	—	Fecal
006	0:05:50:22	Heavy foraging activity, fish near camera	9	Odd	4	5	0	4 On Fish, 1 Shape	—
				Even	8	1	0	Shape	—
				Both	8	1	0	Shape	—
007	0:05:53:13	Heavy foraging activity, fish near camera	8	Odd	4	4	0	On Fish	—
				Even	7	1	0	On Fish	—
				Both	8	0	0	—	—
008	0:05:56:09	Heavy foraging activity, fish near camera	3	Odd	3	0	0	—	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
009	0:06:11:19	Camera deep, fish foraging above.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: June 27,2000 Time: 8:00AM Weather: Sunny Camera Depth: 12-23m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 4.8kg Stocking Density: 7.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:15:50:21	Heavy foraging just above camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	2	—	Fecal
011	0:15:59:08	Heavy foraging just above camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
012	0:16:06:20	Heavy foraging just above camera.	0	Odd	0	0	2	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	3	—	Fecal
013	0:16:48:26	Heavy foraging just above camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	3	—	Fecal
				Both	0	0	3	—	Fecal
014	0:16:51:21	Heavy foraging at camera level.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
015	0:16:53:09	Camera deep, near end of feeding, light foraging above.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
016	0:16:54:24	Camera deep, near end of feeding, light foraging above.	4	Odd	2	2	0	Shape	—
				Even	3	1	0	Shape	—
				Both	4	0	0	—	—
017	0:16:56:11	Camera deep, near end of feeding, light foraging above.	7	Odd	5	2	0	On Fish, Shape	—
				Even	3	4	0	On Fish, Shape	—
				Both	6	1	0	On Fish	—
018	0:16:57:26	Camera deep, near end of feeding, light foraging above.	5	Odd	5	0	0	—	—
				Even	4	1	0	On Fish	—
				Both	5	0	0	—	—

Date: June 27,2000 Time: 8:00AM Weather: Sunny Camera Depth: 12-23m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 4.8kg Stocking Density: 7.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:16:59:17	Camera deep, near end of feeding, light foraging above.	3	Odd	3	0	0	—	—
				Even	3	0	1	—	Fecal
				Both	3	0	1	—	Fecal
020	0:17:01:04	Camera deep, near end of feeding, light foraging above.	5	Odd	3	2	0	Shape	—
				Even	4	1	0	On Fish	—
				Both	5	0	0	—	—
021	0:17:02:20	Camera deep, near end of feeding, light foraging above.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
022	0:17:05:23	Camera deep, near end of feeding, light foraging above.	3	Odd	1	2	0	Shape	—
				Even	3	0	1	—	Camera
				Both	3	0	1	—	Camera
023	0:17:07:03	Camera deep, near end of feeding, light foraging above.	3	Odd	2	1	0	On Fish	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
024	0:17:10:05	Camera deep, near end of feeding, light foraging above.	2	Odd	1	1	2	On Fish	Fecal
				Even	1	1	1	On Fish	Fecal
				Both	1	1	2	On Fish	Fecal
025	0:17:11:24	Camera deep, near end of feeding, light foraging above.	2	Odd	1	1	0	Shape	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
026	0:17:14:29	Camera deep, near end of feeding, light foraging above.	6	Odd	4	2	1	On Fish	Fecal
				Even	4	2	1	On Fish	Fecal
				Both	5	1	1	On Fish	Fecal
027	0:17:20:28	Camera deep, near end of feeding, light foraging above.	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	3	—	Fecal

Date: June 27,2000 Time: 8:00AM Weather: Sunny Camera Depth: 12-23m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 4.8kg Stocking Density: 7.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:17:22:15	Camera deep, near end of feeding, light foraging above.	2	Odd	2	0	0	—	—
				Even	2	0	2	—	Fecal
				Both	2	0	2	—	Fecal
029	0:17:24:01	Camera deep, near end of feeding, light foraging above.	3	Odd	3	0	0	—	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
030	0:17:48:10	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
031	0:17:49:27	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
032	0:17:53:04	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
033	0:17:59:12	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
034	0:18:07:10	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
035	0:18:15:06	End of feeding, camera down deep, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
036	0:03:51:19	Start of feeding, foraging just above camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal

Date: June 27,2000 Time: 8:00AM Weather: Sunny Camera Depth: 12-23m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 4.8kg Stocking Density: 7.8kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:04:06:15	Start of feeding, heavy foraging at camera level.	4	Odd	2	2	0	On Fish	—
				Even	4	0	0	—	—
				Both	4	0	0	—	—
038	0:04:08:13	Start of feeding, heavy foraging at camera level.	4	Odd	3	1	0	On Fish	—
				Even	3	1	0	On Fish	—
				Both	3	1	0	On Fish	—
039	0:04:09:17	Start of feeding, heavy foraging at camera level.	2	Odd	1	1	0	On Fish	—
				Even	0	2	0	On Fish, Shape	—
				Both	1	1	0	On Fish	—
040	0:04:11:05	Start of feeding, heavy foraging at camera level.	2	Odd	1	1	0	On Fish	—
				Even	0	2	0	On Fish	—
				Both	1	1	0	On Fish	—
041	0:04:12:20	Start of feeding, heavy foraging at camera level.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
042	0:04:15:18	Start of feeding, heavy foraging at camera level.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
043	0:04:17:02	Start of feeding, heavy foraging at camera level.	0	Odd	0	0	2	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	2	—	Fecal
044	0:04:18:04	Start of feeding, heavy foraging at camera level.	3	Odd	2	1	1	Shape	Fecal
				Even	1	2	1	On Fish, Shape	Fecal
				Both	2	1	1	Shape	Fecal

Date: June 28,2000 Time: 10:00AM Weather: Sunny Camera Depth: 15-23m Light Intensity: Unknown Water Visibility: 4.2m
Fish Size: 2.8kg Stocking Density: 3.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:17:24:23	Camera deep, light foraging, near end of feeding.	3	Odd	1	2	0	Shape	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
002	0:17:26:15	Camera deep, light foraging, near end of feeding.	6	Odd	4	2	0	Shape	—
				Even	4	2	0	Shape	—
				Both	6	0	0	—	—
003	0:17:28:01	Camera deep, light foraging, near end of feeding.	9	Odd	4	5	0	2 On Fish, 3 Shape	—
				Even	5	4	0	2 On Fish, 2 Shape	—
				Both	7	2	0	On Fish	—
004	0:17:29:22	Camera deep, light foraging, near end of feeding.	12	Odd	7	5	0	2 Overlapping, 3 Shape	—
				Even	10	2	0	Overlapping	—
				Both	10	2	0	Overlapping	—
005	0:17:31:12	Camera deep, light foraging, near end of feeding.	17	Odd	14	3	0	1 On Fish, 2 Shape	—
				Even	11	6	0	3 On Fish, 3 Shape	—
				Both	16	1	0	On Fish	—
006	0:17:33:06	Camera deep, light foraging, near end of feeding.	13	Odd	8	5	0	2 On Fish, 3 Shape	—
				Even	9	4	0	On Fish	—
				Both	11	2	0	On Fish	—
007	0:17:34:29	Camera deep, light foraging, near end of feeding.	11	Odd	8	3	0	1 On Fish, 2 Shape	—
				Even	8	3	0	2 On Fish, 1 Shape	—
				Both	10	1	0	On Fish	—
008	0:17:36:17	Camera deep, light foraging, near end of feeding.	5	Odd	3	2	0	Overlapping	—
				Even	3	2	0	Overlapping	—
				Both	3	2	0	Overlapping	—
009	0:00:16:08	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: June 28,2000 Time: 10:00AM Weather: Sunny Camera Depth: 15-23m Light Intensity: Unknown Water Visibility: 4.2m
Fish Size: 2.8kg Stocking Density: 3.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:00:34:08	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
011	0:00:36:22	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
012	0:00:38:06	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
013	0:00:43:22	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
014	0:00:44:08	Before feeding, fish above camera.	0	Odd	0	0	1	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
015	0:00:46:03	Before feeding, fish above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
016	0:01:14:11	Heavy foraging at camera level.	6	Odd	4	2	0	On Fish	—
				Even	2	4	0	On Fish	—
				Both	4	2	0	On Fish	—
017	0:01:15:24	Heavy foraging at camera level.	6	Odd	4	2	0	On Fish	—
				Even	4	2	0	On Fish	—
				Both	5	1	0	On Fish	—
018	0:01:17:05	Heavy foraging at camera level.	5	Odd	1	4	0	On Fish	—
				Even	4	1	0	On Fish	—
				Both	4	1	0	On Fish	—

Date: June 28,2000 Time: 10:00AM Weather: Sunny Camera Depth: 15-23m Light Intensity: Unknown Water Visibility: 4.2m
Fish Size: 2.8kg Stocking Density: 3.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:01:18:18	Heavy foraging at camera level.	6	Odd	4	2	0	On Fish	—
				Even	5	1	0	On Fish	—
				Both	6	0	0	—	—
020	0:01:53:10	Heavy foraging at camera level.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
021	0:01:54:21	Heavy foraging at camera level.	5	Odd	2	3	0	On Fish	—
				Even	2	3	0	On Fish	—
				Both	3	2	0	On Fish	—
022	0:01:56:04	Heavy foraging at camera level.	5	Odd	4	1	0	On Fish	—
				Even	2	3	0	On Fish	—
				Both	4	1	0	On Fish	—
023	0:01:57:13	Heavy foraging at camera level.	7	Odd	3	4	0	On Fish	—
				Even	3	4	0	On Fish	—
				Both	4	3	0	On Fish	—
024	0:01:58:25	Heavy foraging at camera level.	5	Odd	4	1	0	On Fish	—
				Even	4	1	0	On Fish	—
				Both	5	0	0	—	—
025	0:02:06:16	Heavy foraging at camera level.	5	Odd	5	0	0	—	—
				Even	3	2	0	On Fish	—
				Both	5	0	0	—	—
026	0:02:11:20	Heavy foraging at camera level.	4	Odd	1	3	0	On Fish	—
				Even	2	2	0	On Fish	—
				Both	2	2	0	On Fish	—
027	0:02:13:01	Heavy foraging at camera level.	4	Odd	2	2	0	On Fish	—
				Even	1	3	0	On Fish	—
				Both	2	2	0	On Fish	—

Date: June 28,2000 Time: 10:00AM Weather: Sunny Camera Depth: 15-23m Light Intensity: Unknown Water Visibility: 4.2m
Fish Size: 2.8kg Stocking Density: 3.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:02:14:12	Heavy foraging at camera level.	3	Odd	3	0	0	—	—
				Even	1	2	0	On Fish	—
				Both	3	0	0	—	—
029	0:02:15:25	Heavy foraging at camera level.	3	Odd	0	3	0	On Fish	—
				Even	2	1	0	On Fish	—
				Both	2	1	0	On Fish	—
030	0:02:17:09	Heavy foraging at camera level.	6	Odd	3	3	0	On Fish	—
				Even	2	4	0	On Fish	—
				Both	4	2	0	On Fish	—
031	0:02:18:20	Heavy foraging at camera level.	8	Odd	5	3	0	On Fish	—
				Even	3	5	0	On Fish	—
				Both	5	3	0	On Fish	—
032	0:02:20:05	Heavy foraging at camera level.	7	Odd	5	2	0	On Fish	—
				Even	5	2	0	On Fish	—
				Both	6	1	0	On Fish	—
033	0:02:21:15	Heavy foraging at camera level.	3	Odd	3	0	1	—	Fecal
				Even	3	0	1	—	Fecal
				Both	3	0	1	—	Fecal
034	0:02:22:28	Heavy foraging at camera level.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
035	0:02:24:13	Heavy foraging at camera level.	4	Odd	3	1	0	On Fish	—
				Even	2	2	0	On Fish	—
				Both	4	0	0	—	—
036	0:02:25:25	Heavy foraging at camera level.	5	Odd	2	3	0	On Fish	—
				Even	2	3	0	On Fish	—
				Both	3	2	0	On Fish	—

Date: June 28,2000 Time: 10:00AM Weather: Sunny Camera Depth: 15-23m Light Intensity: Unknown Water Visibility: 4.2m
Fish Size: 2.8kg Stocking Density: 3.6kg/m^3 Pellet Size: 9mm Cage Size: 23m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:02:27:11	Heavy foraging at camera level.	5	Odd	4	1	0	On Fish	—
				Even	3	2	0	On Fish	—
				Both	4	1	0	On Fish	—
038	0:02:28:23	Heavy foraging at camera level.	6	Odd	4	2	0	On Fish	—
				Even	3	3	0	On Fish	—
				Both	5	1	0	On Fish	—
039	0:02:30:06	Heavy foraging at camera level.	11	Odd	5	6	0	On Fish	—
				Even	2	9	0	On Fish	—
				Both	6	5	0	On Fish	—
040	0:02:31:19	Foraging at camera, clearing above.	9	Odd	6	3	0	On Fish	—
				Even	7	2	0	On Fish	—
				Both	7	2	0	On Fish	—
041	0:02:33:06	Foraging at camera, clearing above.	16	Odd	12	4	0	On Fish	—
				Even	12	4	0	On Fish	—
				Both	14	2	0	On Fish	—
042	0:02:34:20	Foraging at camera, clearing above.	10	Odd	7	3	0	On Fish	—
				Even	9	1	0	On Fish	—
				Both	9	1	0	On Fish	—
043	0:02:36:05	Foraging at camera, clearing above.	3	Odd	1	2	0	On Fish	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
044	0:02:37:17	Foraging at camera, clearing above.	3	Odd	1	2	0	On Fish	—
				Even	2	1	0	On Fish	—
				Both	2	1	0	On Fish	—

Date: July 11,2001 Time: 11:30 AM, Weather: Overcast Camera Depth: 14m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 3.0kg Stocking Density: 5.4kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:03:46:27	Before feeding.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
002	0:04:17:05	Fish beginning to forage.	0	Odd	0	0	1	—	Fish
				Even	0	0	0	—	—
				Both	0	0	1	—	Fish
003	0:05:51:06	Fish beginning to forage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
004	0:06:10:22	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
005	0:06:34:16	Light foraging.	0	Odd	0	0	1	—	Fish
				Even	0	0	1	—	Fish
				Both	0	0	2	—	Fish
006	0:07:16:21	Light foraging.	0	Odd	0	0	1	—	Fish
				Even	0	0	0	—	—
				Both	0	0	1	—	Fish
007	0:07:51:12	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:08:39:04	Light foraging.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
009	0:09:16:19	Light foraging.	1	Odd	0	1	0	Shape	—
				Even	0	1	0	Shape	—
				Both	0	1	0	Shape	—

Date: July 11,2001 Time: 11:30 AM, Weather: Overcast Camera Depth: 14m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 3.0kg Stocking Density: 5.4kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:09:23:00	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
011	0:11:21:29	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
012	0:12:27:01	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
013	0:12:58:11	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
014	0:13:31:18	Light foraging.	2	Odd	1	1	0	On Fish	—
				Even	1	1	0	On Fish	—
				Both	1	1	0	On Fish	—
015	0:15:07:13	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
016	0:16:21:29	Light foraging.	1	Odd	0	1	0	On Fish	—
				Even	0	1	2	On Fish	Fecal
				Both	0	1	2	On Fish	Fecal
017	0:16:55:12	Light foraging.	2	Odd	2	0	0	—	—
				Even	1	1	1	On Fish	Fecal
				Both	2	0	1	—	Fecal
018	0:17:14:12	Moderate foraging.	6	Odd	3	3	0	On Fish	—
				Even	3	3	0	On Fish	—
				Both	4	2	0	On Fish	—

Date: July 11,2001 Time: 11:30 AM, Weather: Overcast Camera Depth: 14m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 3.0kg Stocking Density: 5.4kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:17:39:00	Moderate foraging.	3	Odd	3	0	1	—	Camera
				Even	2	1	0	Shape	—
				Both	3	0	1	—	Camera
020	0:18:33:00	Moderate foraging.	3	Odd	1	2	0	On Fish, Shape	—
				Even	2	1	0	On Fish	—
				Both	2	1	0	On Fish	—
021	0:19:39:07	Moderate foraging.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
022	0:19:57:03	Moderate foraging.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
023	0:20:29:08	Moderate foraging.	4	Odd	3	1	0	On Fish	—
				Even	3	1	0	On Fish	—
				Both	3	1	0	On Fish	—
024	0:20:45:24	Moderate foraging.	0	Odd	0	0	1	—	Fish
				Even	0	0	2	—	Fecal, Fish
				Both	0	0	2	—	Fecal, Fish
025	0:21:17:27	Moderate foraging.	2	Odd	1	1	1	—	Camera
				Even	2	0	2	—	Camera, Fecal
				Both	2	0	2	—	Camera, Fecal
026	0:22:32:21	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	1	0	2	—	Camera, Fecal
				Both	1	0	2	—	Camera, Fecal
027	0:23:16:03	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—

Date: July 11,2001 Time: 11:30 AM, Weather: Overcast Camera Depth: 14m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 3.0kg Stocking Density: 5.4kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
028	0:23:40:23	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	0	1	0	Shape	—
				Both	1	0	0	—	—
029	0:25:07:06	Moderate foraging.	4	Odd	3	1	0	Shape	—
				Even	4	0	1	—	Camera
				Both	4	0	1	—	Camera
030	0:25:17:14	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
031	0:25:24:18	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	0	1	0	Shape	—
				Both	1	0	0	—	—
032	0:25:42:08	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
033	0:26:27:00	Light foraging.	2	Odd	1	1	1	On Fish	Fish
				Even	1	1	2	On Fish	Fecal, Fish
				Both	1	1	2	On Fish	Fecal, Fish
028	0:23:40:23	Moderate foraging.	1	Odd	1	0	0	—	—
				Even	0	1	0	Shape	—
				Both	1	0	0	—	—
034	0:26:35:10	Light foraging.	2	Odd	0	2	0	On Fish	—
				Even	0	2	0	On Fish	—
				Both	0	2	0	On Fish	—
035	0:26:56:25	Light foraging.	1	Odd	1	0	1	—	Fecal
				Even	1	0	0	—	—
				Both	1	0	1	—	Fecal

Date: July 11,2001 Time: 11:30 AM, Weather: Overcast Camera Depth: 14m Light Intensity: Unknown Water Visibility: 5.0m
Fish Size: 3.0kg Stocking Density: 5.4kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	0	—	—
036	0:27:34:16	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
037	0:27:50:22	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	1	0	2	—	Fish
038	0:28:21:16	End of feeding.	1	Even	1	0	0	—	—
				Both	1	0	2	—	Fish
				Odd	0	0	0	—	—
039	0:28:47:04	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
040	0:29:00:02	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
041	0:29:24:27	End of feeding.	0	Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
				Odd	0	0	1	—	Fish
042	0:29:39:07	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	1	—	Fish
				Odd	0	0	1	—	Fecal
043	0:29:47:14	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
				Odd	0	0	0	—	—
044	0:29:53:20	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 11,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.0m
Fish Size: 2.4kg Stocking Density: 4.8kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:00:22:17	Before feeding.	0	Odd	0	0	1	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
002	0:01:18:25	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
003	0:01:20:00	Light foraging.	4	Odd	2	2	0	On Fish	—
				Even	3	1	0	On Fish	—
				Both	3	1	0	On Fish	—
004	0:01:30:00	Light foraging.	6	Odd	5	1	1	On fish	Fecal
				Even	6	0	0	—	—
				Both	6	0	1	—	Fecal
005	0:01:44:00	Light foraging.	5	Odd	1	4	0	On Fish	—
				Even	1	4	0	On Fish	—
				Both	1	4	0	On Fish	—
006	0:02:14:00	Light foraging.	11	Odd	3	8	0	On Fish	—
				Even	3	8	1	On Fish	—
				Both	3	8	1	On Fish	—
007	0:02:40:00	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:02:57:24	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
009	0:03:27:14	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 11,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.0m
Fish Size: 2.4kg Stocking Density: 4.8kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:04:03:11	Heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
011	0:04:50:06	Heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
012	0:05:09:22	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
013	0:05:59:02	Light foraging.	1	Odd	0	1	0	On Fish	—
				Even	0	1	0	On Fish	—
				Both	0	1	0	On Fish	—
014	0:06:46:29	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
015	0:07:17:09	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
016	0:08:14:13	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
017	0:09:53:10	Light foraging.	1	Odd	1	0	0	—	—
				Even	1	0	0	—	—
				Both	1	0	0	—	—
018	0:11:46:16	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 11,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.0m
Fish Size: 2.4kg Stocking Density: 4.8kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
019	0:12:05:24	Light foraging.	3	Odd	2	1	1	On Fish	Fecal
				Even	3	0	1	—	Fecal
				Both	3	0	1	—	Fecal
020	0:12:41:11	Light foraging.	9	Odd	4	5	0	On Fish	—
				Even	5	4	0	On Fish	—
				Both	5	4	0	On Fish	—
021	0:13:17:09	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
022	0:13:34:09	Light foraging.	0	Odd	0	0	2	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	2	—	Fecal
023	0:14:31:24	Light foraging.	6	Odd	3	3	2	On Fish	Fecal
				Even	4	2	0	On Fish	—
				Both	4	2	2	On Fish	Fecal
024	0:15:03:02	Light foraging.	0	Odd	0	0	1	—	Fecal
				Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
025	0:15:46:20	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
026	0:16:10:24	Light foraging.	7	Odd	5	2	0	On Fish	—
				Even	5	2	1	On Fish	Fecal
				Both	5	2	1	On Fish	Fecal
027	0:16:52:02	Light foraging.	3	Odd	3	0	2	—	Fecal
				Even	3	0	1	—	Fecal
				Both	3	0	2	—	Fecal

Date: July 11,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.0m
Fish Size: 2.4kg Stocking Density: 4.8kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	2	0	3	—	Fecal
028	0:17:23:22	Light foraging.	2	Even	2	0	2	—	Fecal
				Both	2	0	3	—	Fecal
				Odd	1	0	2	—	Fecal
029	0:17:43:26	Light foraging.	1	Even	1	0	3	—	Fecal
				Both	1	0	3	—	Fecal
				Odd	4	1	2	On Fish	Fecal
030	0:18:40:11	Light foraging.	5	Even	4	1	1	On Fish	Fecal
				Both	4	1	2	On Fish	Fecal
				Odd	2	1	2	On Fish	Fecal
031	0:19:34:15	Light foraging.	3	Even	2	1	1	On Fish	Fecal
				Both	2	1	2	On Fish	Fecal
				Odd	0	0	0	—	—
032	0:19:54:21	Very light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	1	2	Shape	Fecal
033	0:20:07:14	Very light foraging.	1	Even	0	1	1	Shape	Fecal
				Both	0	1	3	Shape	Fecal
				Odd	2	5	1	On Fish	Fecal
034	0:20:54:25	Very light foraging.	7	Even	1	6	1	On Fish	Fecal
				Both	2	5	1	On Fish	Fecal
				Odd	0	0	0	—	—
035	0:21:44:22	Very light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	1	0	1	—	Fecal
036	0:23:19:00	Very light foraging.	1	Even	1	0	1	—	Fecal
				Both	1	0	1	—	Fecal

Date: July 11,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.0m
Fish Size: 2.4kg Stocking Density: 4.8kg/m^3 Pellet Size: 8.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:24:07:12	Very light foraging.	1	Odd	1	0	3	—	Fecal
				Even	1	0	2	—	Fecal
				Both	1	0	3	—	Fecal
038	0:25:23:10	Very light foraging.	3	Odd	3	0	0	—	—
				Even	3	0	0	—	—
				Both	3	0	0	—	—
039	0:28:38:29	Very light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
040	0:29:09:29	Very light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
041	0:29:42:27	Very light foraging.	2	Odd	2	0	0	—	—
				Even	2	0	0	—	—
				Both	2	0	0	—	—
042	0:30:08:29	Very light foraging.	0	Odd	0	0	2	—	Fecal
				Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
043	0:30:36:11	Very light foraging.	1	Odd	1	0	1	—	Fecal
				Even	1	0	2	—	Fecal
				Both	1	0	2	—	Fecal
044	0:31:17:21	Very light foraging.	2	Odd	2	0	2	—	Fecal, Fish
				Even	2	0	0	—	—
				Both	2	0	2	—	Fecal, Fish

Date: July 12,2001 Time: 10:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
001	0:00:22:28	No fish in image.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
002	0:00:46:01	Fish beginning to forage.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
003	0:01:46:26	Fish foraging above camera.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
004	0:02:34:12	Heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
005	0:03:14:21	Heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
006	0:04:25:10	Heavy foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
007	0:06:17:00	Moderate foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
008	0:08:55:12	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—
009	0:10:20:19	Light foraging.	0	Odd	0	0	0	—	—
				Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 12,2001 Time: 10:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	0	—	—
010	0:12:20:21	Very little foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
011	0:14:41:27	Very little foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
012	0:15:58:15	Very light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
013	0:17:12:17	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
014	0:18:28:00	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
015	0:19:24:09	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
016	0:20:15:17	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
017	0:20:48:05	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
018	0:21:58:11	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—

Date: July 12,2001 Time: 10:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	0	—	—
019	0:22:31:07	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
020	0:23:35:04	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
021	0:24:19:18	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	0	—	—
022	0:25:39:27	Moderate foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	1	0	0	—	—
023	0:26:07:10	Moderate foraging.	1	Even	1	0	0	—	—
				Both	1	0	0	—	—
				Odd	0	0	1	—	Fish
024	0:26:27:20	Light foraging.	0	Even	0	0	1	—	Fish
				Both	0	0	2	—	Fish
				Odd	0	0	0	—	—
025	0:28:51:18	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	1	0	1	—	Camera
026	0:34:17:21	Light foraging.	1	Even	1	0	0	—	—
				Both	1	0	1	—	Camera
				Odd	2	0	1	—	Fish
027	0:38:29:23	Light foraging.	2	Even	2	0	0	—	—
				Both	2	0	1	—	Fish

Date: July 12,2001 Time: 10:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	0	—	—
028	0:39:15:14	Light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	3	0	1	—	Fecal
029	0:41:21:09	Light foraging.	3	Even	3	0	1	—	Fecal
				Both	3	0	1	—	Fecal
				Odd	2	2	0	On Fish	—
030	0:41:47:28	Light foraging.	4	Even	2	2	1	On Fish	Fish
				Both	3	1	1	On Fish	Fish
				Odd	2	0	1	—	Fecal
031	0:42:06:17	Light foraging.	2	Even	2	0	1	—	Fecal
				Both	2	0	1	—	Fecal
				Odd	2	0	0	—	—
032	0:42:18:03	Light foraging.	2	Even	2	0	0	—	—
				Both	2	0	0	—	—
				Odd	1	2	0	On Fish	—
033	0:42:52:14	Light foraging.	3	Even	1	2	0	On Fish	—
				Both	2	1	0	On Fish	—
				Odd	5	3	0	On Fish	—
034	0:43:12:05	Heavy foraging.	8	Even	4	4	0	On Fish	—
				Both	5	3	0	On Fish	—
				Odd	2	2	0	On Fish	—
035	0:43:22:22	Heavy foraging.	4	Even	2	2	0	On Fish	—
				Both	2	2	0	On Fish	—
				Odd	1	0	2	—	Camera, Fecal
036	0:43:40:25	Heavy foraging.	1	Even	1	0	0	—	—
				Both	1	0	2	—	Camera, Fecal

Date: July 12,2001 Time: 10:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	1	0	1	—	Fecal
037	0:43:53:00	Heavy foraging.	1	Even	1	0	1	—	Fecal
				Both	1	0	1	—	Fecal
				Odd	1	2	0	On Fish	—
038	0:44:37:16	Heavy foraging.	3	Even	2	1	1	On Fish	Fecal
				Both	2	1	1	On Fish	Fecal
				Odd	0	0	2	—	Camera, Fecal
039	0:45:28:23	Very light foraging.	0	Even	0	0	0	—	—
				Both	0	0	2	—	Camera, Fecal
				Odd	0	0	0	—	—
040	0:46:40:06	Very light foraging.	0	Even	0	0	0	—	—
				Both	0	0	0	—	—
				Odd	0	0	1	—	Fecal
041	0:47:12:16	End of feeding.	0	Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal
				Odd	0	0	1	—	Fish
042	0:48:16:04	End of feeding.	0	Even	0	0	0	—	—
				Both	0	0	1	—	Fish
				Odd	0	0	2	—	Fecal
043	0:48:27:05	End of feeding.	0	Even	0	0	2	—	Fecal
				Both	0	0	2	—	Fecal
				Odd	0	0	1	—	Fecal
044	0:49:41:17	End of feeding.	0	Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal

Date: July 12,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	1	—	Fecal
001	0:00:06:06	Heavy foraging.	0	Even	0	0	0	—	—
				Both	0	0	1	—	Fecal
				Odd	0	0	1	—	Fecal
002	0:00:17:01	Heavy foraging.	0	Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
				Odd	5	4	0	On Fish	—
003	0:00:48:08	Heavy foraging.	9	Even	5	4	1	On Fish	Fecal
				Both	7	2	1	On Fish	Fecal
				Odd	14	0	0	—	—
004	0:01:40:04	Heavy foraging.	14	Even	12	2	0	On Fish	—
				Both	14	0	0	—	—
				Odd	6	2	1	On Fish	Camera
005	0:02:05:17	Heavy foraging.	8	Even	7	1	1	On Fish	Camera
				Both	7	1	2	On Fish	Camera
				Odd	9	6	1	4 On Fish, 2 Shape	Fish
006	0:02:27:22	Heavy foraging.	15	Even	12	3	0	2 On Fish, 1 Shape	—
				Both	14	1	1	Shape	Fish
				Odd	10	4	2	1 On Fish, 3 Shape	Fecal
007	0:02:42:28	Heavy foraging.	14	Even	9	5	0	3 On Fish, 2 Shape	—
				Both	13	1	2	On Fish	Fecal
				Odd	13	7	1	On Fish	Fish
008	0:03:00:03	Heavy foraging.	20	Even	16	4	0	On Fish	—
				Both	19	1	1	On Fish	Fish
				Odd	12	3	1	On Fish	Fecal
009	0:04:41:03	Heavy foraging.	15	Even	12	3	1	On Fish	Fecal
				Both	13	2	1	On Fish	Fecal

Date: July 12,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	8	2	0	On Fish	—
010	0:05:22:17	Heavy foraging.	10	Even	8	2	0	On Fish	—
				Both	9	1	0	On Fish	—
				Odd	8	0	2	—	Fecal
011	0:05:49:25	Heavy foraging.	8	Even	8	0	2	—	Fecal
				Both	8	0	3	—	Fecal
				Odd	15	4	0	On Fish	—
012	0:10:04:04	Heavy foraging.	19	Even	14	5	0	On Fish	—
				Both	18	1	0	On Fish	—
				Odd	19	3	0	On Fish	—
013	0:11:59:02	Heavy foraging.	22	Even	17	5	0	On Fish	—
				Both	20	2	0	On Fish	—
				Odd	9	1	0	On Fish	—
014	0:12:28:05	Heavy foraging.	10	Even	8	2	0	On Fish	—
				Both	9	1	0	On Fish	—
				Odd	19	10	0	6 On fish, 4 Shape	—
015	0:13:36:15	Heavy foraging.	29	Even	19	10	0	5On fish, 5 Shape	—
				Both	24	5	0	On Fish	—
				Odd	11	5	0	2 On fish, 3 Shape	—
016	0:15:30:17	Heavy foraging.	16	Even	11	5	0	3On fish, 2 Shape	—
				Both	14	2	0	On Fish, Shape	—
				Odd	2	3	0	On Fish	—
017	0:15:48:02	Heavy foraging.	5	Even	4	1	0	On Fish	—
				Both	4	1	0	On Fish	—
				Odd	13	4	0	On Fish	—
018	0:17:11:00	Heavy foraging.	17	Even	7	10	0	5 On Fish, 5 Shape	—
				Both	14	3	0	On Fish	—

Date: July 12,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	3	3	1	On Fish	Fecal
019	0:17:56:27	Heavy foraging.	6	Even	4	2	1	On Fish	Fecal
				Both	5	1	2	On Fish	Fecal
				Odd	2	1	0	On Fish	—
020	0:18:05:12	Moderate foraging.	3	Even	1	2	0	On Fish, Shape	—
				Both	2	1	0	On Fish	—
				Odd	2	3	0	On Fish	—
021	0:19:27:19	Moderate foraging.	5	Even	2	3	0	1 On Fish, 2 Shape	—
				Both	3	2	0	On Fish	—
				Odd	3	0	0	—	—
022	0:21:27:25	Moderate foraging.	3	Even	2	1	0	On Fish	—
				Both	3	0	0	—	—
				Odd	12	5	1	3 On Fish, 2 Shape	Fecal
023	0:22:11:06	Moderate foraging.	17	Even	9	8	1	5 On Fish, 3 Shape	Fecal
				Both	15	2	2	On Fish	Fecal
				Odd	10	3	0	2 On Fish, 1 Shape	—
024	0:23:29:07	Moderate foraging.	13	Even	10	3	2	2 On Fish, 1 Shape	Fecal
				Both	11	2	2	On Fish, Shape	Fecal
				Odd	10	0	1	—	Fecal
025	0:23:42:21	Moderate foraging.	10	Even	6	4	2	2 On fish, 2 Shape	Fecal
				Both	10	0	2	—	Fecal
				Odd	5	1	0	On Fish	—
026	0:24:43:18	Moderate foraging.	6	Even	3	3	0	On Fish	—
				Both	5	1	0	On Fish	—
				Odd	13	2	0	On Fish	—
027	0:25:26:09	Moderate foraging.	15	Even	12	3	0	On Fish	—
				Both	13	2	0	On Fish	—

Date: July 12,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: $2.3kg/m^3$ Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	8	1	1	—	Fecal
028	0:26:18:11	Moderate foraging.	9	Even	8	1	0	—	—
				Both	8	1	1	—	Fecal
				Odd	7	7	0	On Fish	—
029	0:26:34:14	Moderate foraging.	14	Even	11	3	0	On Fish	—
				Both	12	2	0	On Fish	—
				Odd	15	2	1	On Fish	Fecal
030	0:28:31:08	Moderate foraging.	17	Even	15	2	1	On Fish	Fecal
				Both	17	0	2	—	Fecal
				Odd	7	3	1	On Fish	Fecal
031	0:28:59:11	Moderate foraging.	10	Even	3	7	1	3 On Fish, 4 Shape	Fecal
				Both	7	3	1	On Fish	Fecal
				Odd	7	4	1	On Fish	Fish
032	0:29:39:19	Moderate foraging.	11	Even	9	2	0	On Fish	—
				Both	10	1	1	On Fish	Fish
				Odd	2	0	0	—	—
033	0:30:55:15	Moderate foraging.	2	Even	2	0	1	—	Camera
				Both	2	0	1	—	Camera
				Odd	1	0	3	—	Fecal
034	0:31:11:29	Moderate foraging.	1	Even	0	1	3	On Fish	Fecal
				Both	1	0	4	—	Fecal
				Odd	0	0	1	—	Fecal
035	0:31:35:27	Light foraging.	0	Even	0	0	1	—	Fecal
				Both	0	0	2	—	Fecal
				Odd	0	0	1	—	Fecal
036	0:32:17:08	Light foraging.	0	Even	0	0	1	—	Fecal
				Both	0	0	1	—	Fecal

Date: July 12,2001 Time: 5:30 PM, Weather: Sunny Camera Depth: 4.5m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 1.1kg Stocking Density: 2.3kg/m^3 Pellet Size: 6.5mm Cage Size: 31m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:33:13:21	Light foraging.	9	Odd	7	2	0	Shape	—
				Even	6	3	0	Shape	—
				Both	8	1	0	Shape	—
038	0:34:41:00	Light foraging.	21	Odd	14	7	0	4 On Fish, 3 Shape	—
				Even	15	6	0	4 On Fish, 2 Shape	—
				Both	18	3	0	1 On Fish, 2 Shape	—
039	0:35:29:28	Light foraging.	5	Odd	4	1	0	Shape	—
				Even	3	2	1	Shape	Camera
				Both	4	1	1	Shape	Camera
040	0:36:48:21	Light foraging.	5	Odd	5	0	2	—	Fecal
				Even	4	1	0	Shape	—
				Both	5	0	2	—	Fecal
041	0:39:14:09	Light foraging.	5	Odd	2	3	0	Shape	—
				Even	5	0	0	—	—
				Both	5	0	0	—	—
042	0:40:22:28	Light foraging.	0	Odd	0	0	2	—	Fecal
				Even	0	0	0	—	—
				Both	0	0	2	—	Fecal
043	0:41:36:00	Light foraging.	5	Odd	3	2	3	Shape	—
				Even	3	2	3	Shape	—
				Both	5	0	6	—	—
044	0:43:56:18	Light foraging.	2	Odd	2	0	2	—	Fecal
				Even	2	0	3	—	Fecal
				Both	2	0	3	—	Fecal

Date: July 13,2001 Time: 9:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 0.025kg Stocking Density: 0.27kg/m^3 Pellet Size: 2.0mm Cage Size: 12.5m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	0	0	1	—	Camera
001	0:01:02:12	Before feeding.	0	Even	0	0	1	—	Camera
				Both	0	0	1	—	Camera
				Odd	1	0	2	—	Camera
002	0:02:55:17	Before feeding.	1	Even	1	0	1	—	Camera
				Both	1	0	2	—	Camera
				Odd	0	1	2	Shape	Camera
003	0:06:53:23	Fish beginning to forage.	1	Even	1	0	2	—	Camera
				Both	1	0	2	—	Camera
				Odd	0	0	1	—	Camera
004	0:07:56:09	Light foraging.	0	Even	0	0	1	—	Camera
				Both	0	0	1	—	Camera
				Odd	1	1	1	Shape	Camera
005	0:08:26:19	Light foraging.	2	Even	2	0	1	—	Camera
				Both	2	0	1	—	Camera
				Odd	5	1	2	Shape	Camera
006	0:08:59:17	Light foraging.	6	Even	5	1	1	Shape	Camera
				Both	6	0	2	—	Camera
				Odd	4	0	1	—	Camera
007	0:10:07:16	Light foraging.	4	Even	2	2	1	On Fish, Shape	Camera
				Both	4	0	1	—	Camera
				Odd	3	1	2	Shape	Camera
008	0:11:43:13	Light foraging.	4	Even	4	0	2	—	Camera
				Both	4	0	2	—	Camera
				Odd	0	0	2	—	Camera
009	0:12:20:02	Light foraging.	0	Even	0	0	3	—	Camera
				Both	0	0	4	—	Camera

Date: July 13,2001 Time: 9:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 0.025kg Stocking Density: 0.27kg/m^3 Pellet Size: 2.0mm Cage Size: 12.5m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
010	0:13:10:24	Light foraging.	1	Odd	1	0	2	—	Camera
				Even	1	0	2	—	Camera
				Both	1	0	2	—	Camera
011	0:14:01:19	Light foraging.	1	Odd	1	0	1	—	Camera
				Even	1	0	0	—	—
				Both	1	0	1	—	Camera
012	0:15:11:28	Light foraging.	3	Odd	3	0	2	—	Camera, Fish
				Even	2	1	1	Shape	Camera
				Both	3	0	2	—	Camera, Fish
013	0:12:58:11	Light foraging.	3	Odd	3	0	1	—	Camera
				Even	3	0	1	—	Camera
				Both	3	0	1	—	Camera
014	0:13:31:18	Light foraging.	2	Odd	2	0	1	—	Camera
				Even	2	0	1	—	Camera
				Both	2	0	1	—	Camera
015	0:15:07:13	Light foraging.	1	Odd	1	0	1	—	Camera
				Even	1	0	1	—	Camera
				Both	1	0	1	—	Camera
016	0:16:21:29	Light foraging.	6	Odd	4	2	1	On Fish	Camera
				Even	4	2	1	On Fish	Camera
				Both	6	0	1	—	Camera
017	0:16:55:12	Light foraging.	4	Odd	2	2	1	On Fish, Shape	Camera
				Even	3	1	1	On Fish	Camera
				Both	3	1	1	On Fish	Camera
018	0:17:14:12	Light foraging.	8	Odd	6	2	2	On Fish, Shape	Camera
				Even	5	3	1	2 On Fish, 1 Shape	Camera
				Both	8	0	2	—	Camera

Date: July 13,2001 Time: 9:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 0.025kg Stocking Density: 0.27kg/m^3 Pellet Size: 2.0mm Cage Size: 12.5m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	9	1	1	On Fish	Camera
019	0:17:39:00	Light foraging.	10	Even	8	2	4	On Fish	3 Camera, 1 Fecal
				Both	10	0	4	—	3 Camera, 1 Fecal
				Odd	4	0	5	—	Camera
020	0:18:33:00	Light foraging.	4	Even	2	2	4	Shape	Camera
				Both	4	0	5	—	Camera
				Odd	5	0	5	—	Camera
021	0:19:39:07	Light foraging.	5	Even	4	1	3	On Fish	Camera
				Both	5	0	5	—	Camera
				Odd	3	1	3	On Fish	Camera
022	0:19:57:03	Light foraging.	4	Even	2	2	4	On Fish, Shape	Camera
				Both	3	1	4	On Fish	Camera
				Odd	5	0	2	—	Camera
023	0:20:29:08	Light foraging.	5	Even	5	0	4	—	3 Camera, 1 Fecal
				Both	5	0	4	—	3 Camera, 1 Fecal
				Odd	5	0	6	—	Camera
024	0:20:45:24	Light foraging.	5	Even	4	1	3	Shape	Camera
				Both	5	0	6	—	Camera
				Odd	7	0	4	—	Camera
025	0:21:17:27	Light foraging.	7	Even	6	1	4	Shape	Camera
				Both	7	0	4	—	Camera
				Odd	1	1	4	On Fish	Camera
026	0:22:32:21	Light foraging.	2	Even	0	2	3	On Fish, Shape	Camera
				Both	1	1	5	On Fish	Camera
				Odd	2	0	3	—	Camera
027	0:23:16:03	Light foraging.	2	Even	2	0	1	—	Camera
				Both	2	0	3	—	Camera

Date: July 13,2001 Time: 9:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 0.025kg Stocking Density: 0.27kg/m^3 Pellet Size: 2.0mm Cage Size: 12.5m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
				Odd	14	2	0	On Fish	—
028	0:23:40:23	Light foraging.	16	Even	12	4	1	3 On Fish, 1 Shape	Camera
				Both	14	2	1	On Fish	Camera
				Odd	4	0	0	—	—
029	0:25:07:06	Light foraging.	4	Even	3	1	2	Shape	Camera
				Both	4	0	2	—	Camera
				Odd	1	1	1	Shape	Camera
030	0:25:17:14	Light foraging.	2	Even	1	1	3	Shape	1 Camera, 2 Fecal
				Both	1	1	3	Shape	1 Camera, 2 Fecal
				Odd	1	0	1	—	Camera
031	0:25:24:18	Light foraging.	1	Even	0	1	1	On Fish	Camera
				Both	1	0	1	—	Camera
				Odd	6	1	0	Shape	—
032	0:25:42:08	Light foraging.	7	Even	6	1	0	On Fish	—
				Both	7	0	0	—	—
				Odd	4	0	1	—	Camera
033	0:26:27:00	Light foraging.	4	Even	4	0	2	—	Camera
				Both	4	0	2	—	Camera
				Odd	4	0	2	—	Camera
034	0:26:35:10	Light foraging.	4	Even	4	0	0	—	—
				Both	4	0	2	—	Camera
				Odd	3	0	2	—	Camera, Fecal
035	0:26:56:25	Light foraging.	3	Even	3	0	3	—	Camera
				Both	3	0	5	—	4 Camera, 1 Fecal
				Odd	6	0	1	—	Camera
036	0:27:34:16	Light foraging.	6	Even	3	3	1	Shape	Camera
				Both	6	0	1	—	Camera

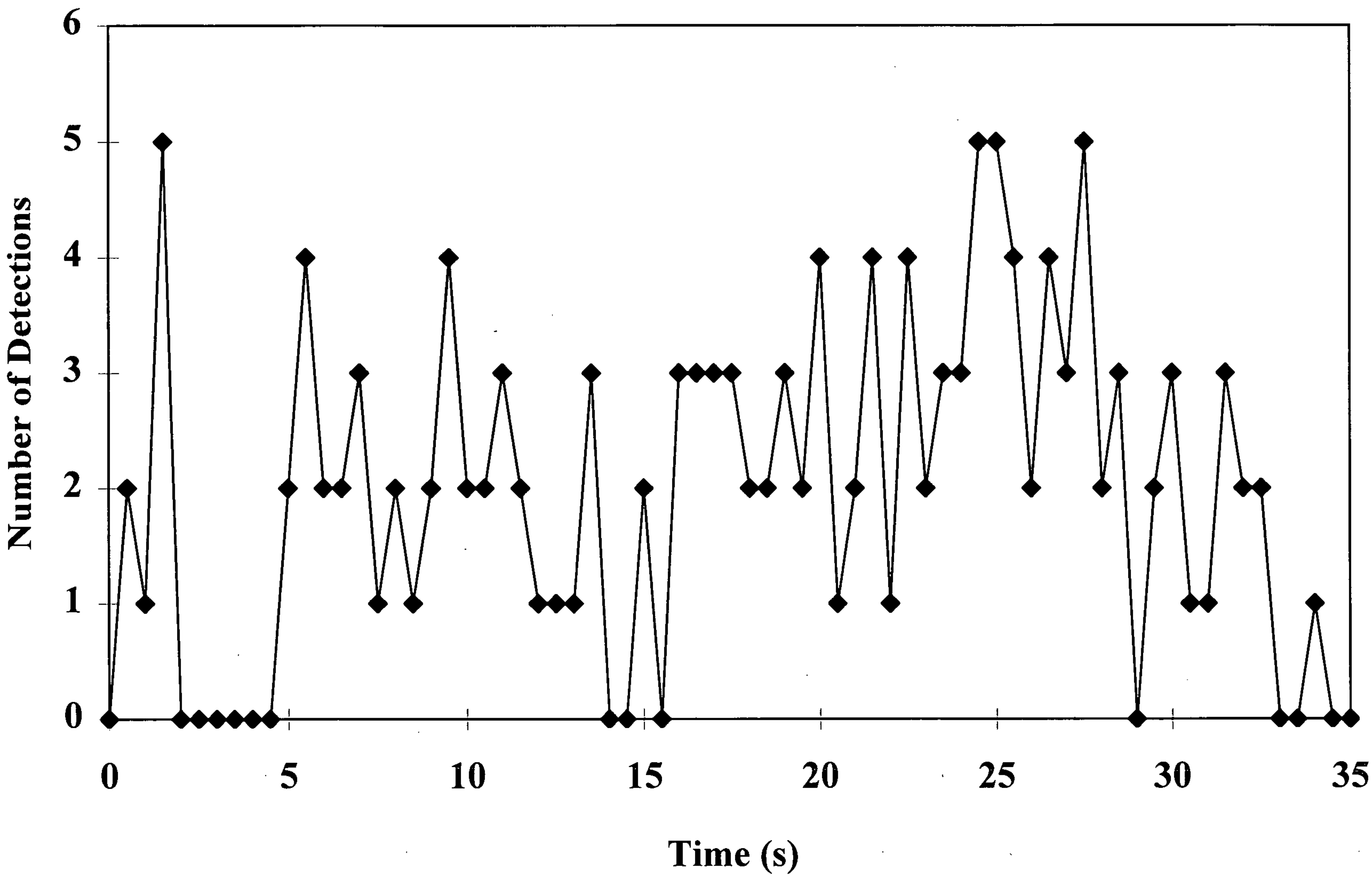
Date: July 13,2001 Time: 9:00 AM, Weather: Overcast Camera Depth: 14m Light Intensity: unknown Water Visibility: 5.5m
Fish Size: 0.025kg Stocking Density: 0.27kg/m^3 Pellet Size: 2.0mm Cage Size: 12.5m

Image	VCR Time	Image Description	Pellets In Image	Field	Pellets Detected	Pellets Not Detected	False Detections	Reason That Pellets Were Not Detected	Reason For False Detections
037	0:27:50:22	Light foraging.	2	Odd	1	1	2	Shape	Camera
				Even	2	0	2	—	Camera
				Both	2	0	3	—	Camera
038	0:28:21:16	Light foraging.	2	Odd	1	1	1	Shape	Camera
				Even	1	1	1	Shape	Camera
				Both	2	0	1	—	Camera
039	0:28:47:04	Light foraging.	1	Odd	1	0	1	—	Camera
				Even	1	0	1	—	Camera
				Both	1	0	1	—	Camera
040	0:29:00:02	Light foraging.	3	Odd	3	0	1	—	Camera
				Even	2	1	3	Shape	Camera
				Both	3	0	3	—	Camera
041	0:29:24:27	Light foraging.	1	Odd	1	0	1	—	Camera
				Even	1	0	1	—	Camera
				Both	1	0	1	—	Camera
042	0:29:39:07	Light foraging.	3	Odd	3	0	1	—	Camera
				Even	3	0	1	—	Camera
				Both	3	0	1	—	Camera
043	0:29:47:14	Light foraging.	3	Odd	3	0	1	—	Camera
				Even	3	0	1	—	Camera
				Both	3	0	1	—	Camera
044	0:29:53:20	Light foraging.	2	Odd	2	0	4	—	3 Camera, 1 Fecal
				Even	1	1	2	Shape	Camera
				Both	2	0	4	—	3 Camera, 1 Fecal

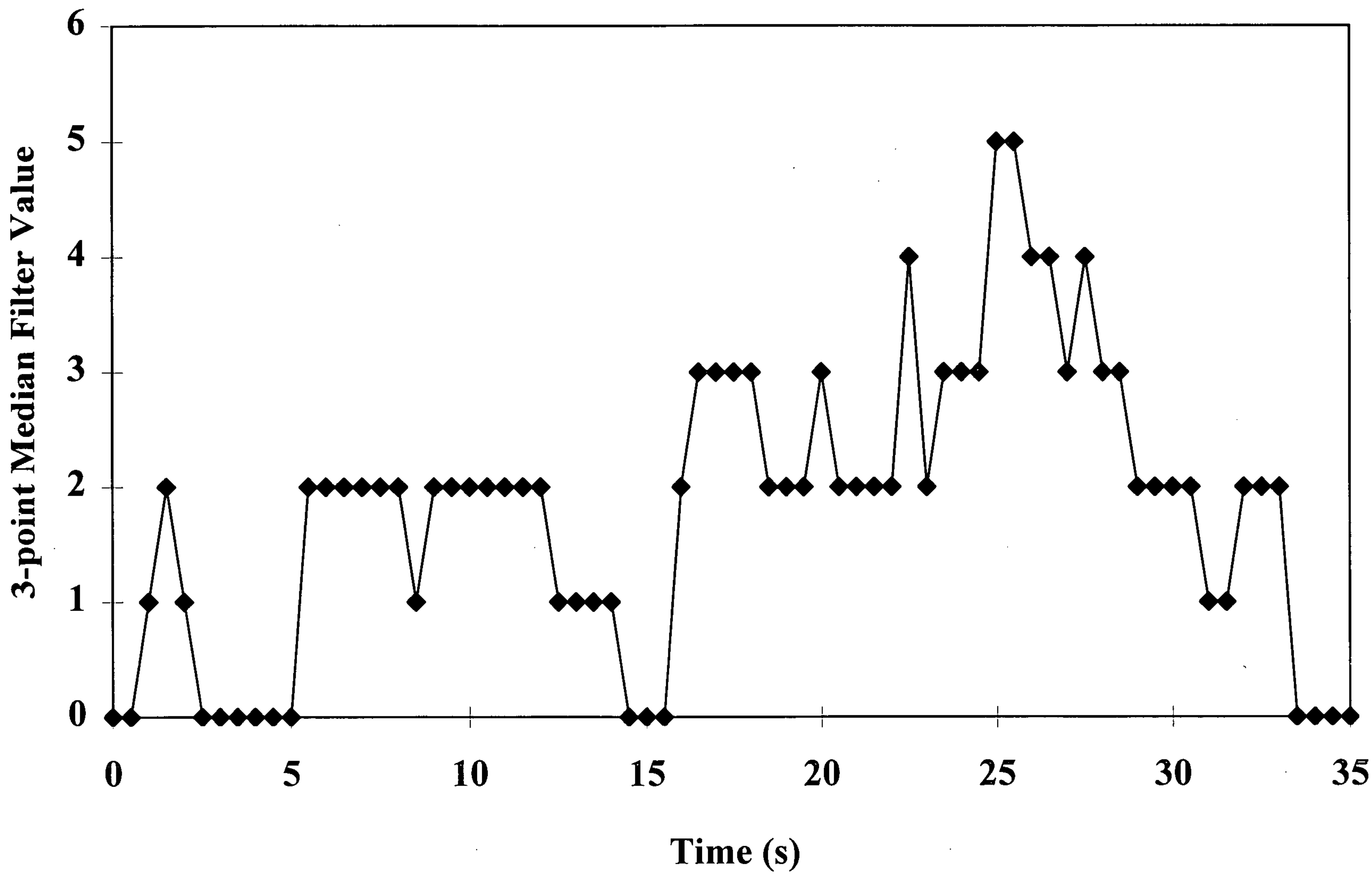
Appendix A.2

Pellet Alarm Testing

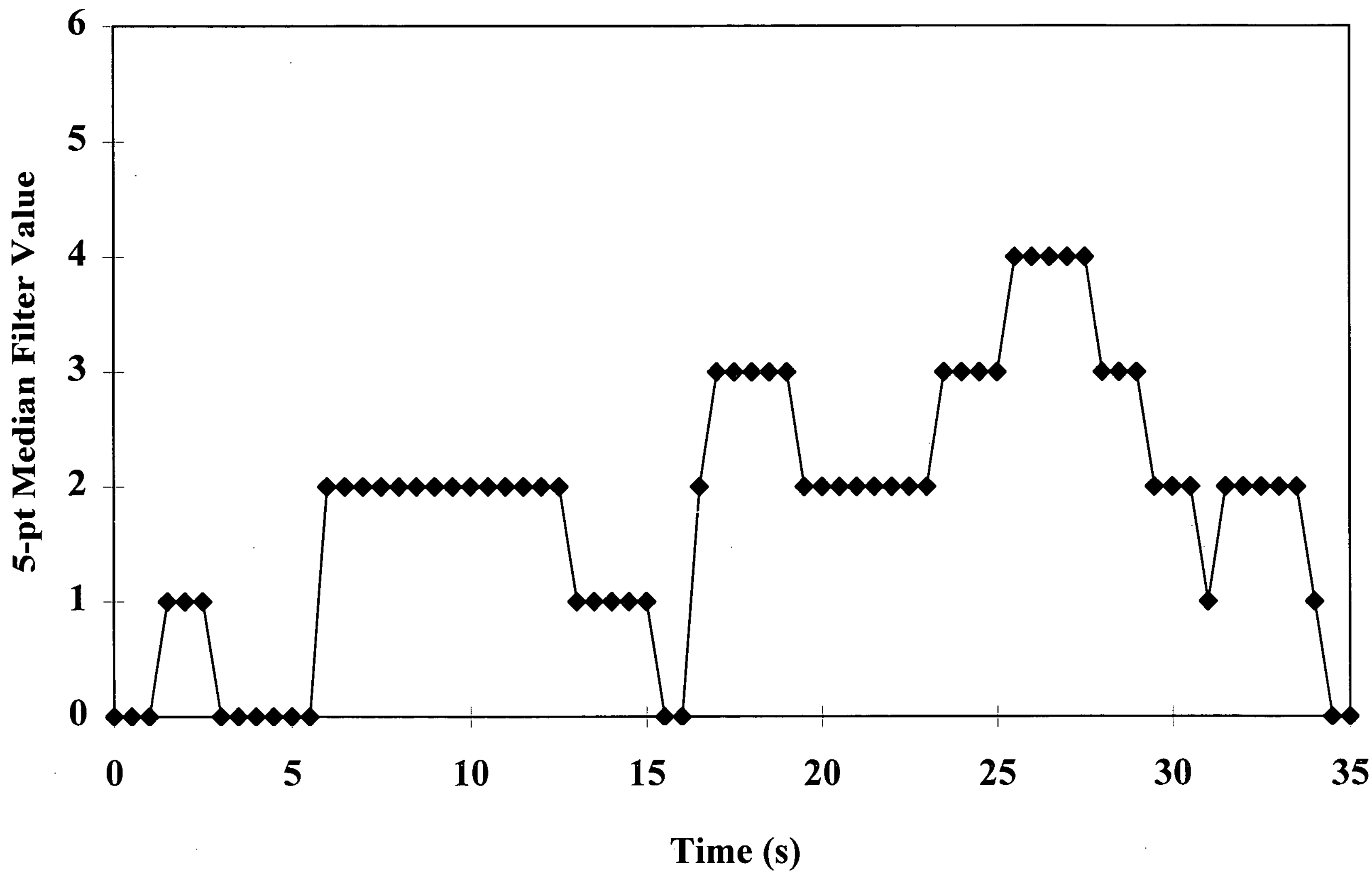
Example of a high rate of false detections (sampling rate = 2 frames per second).



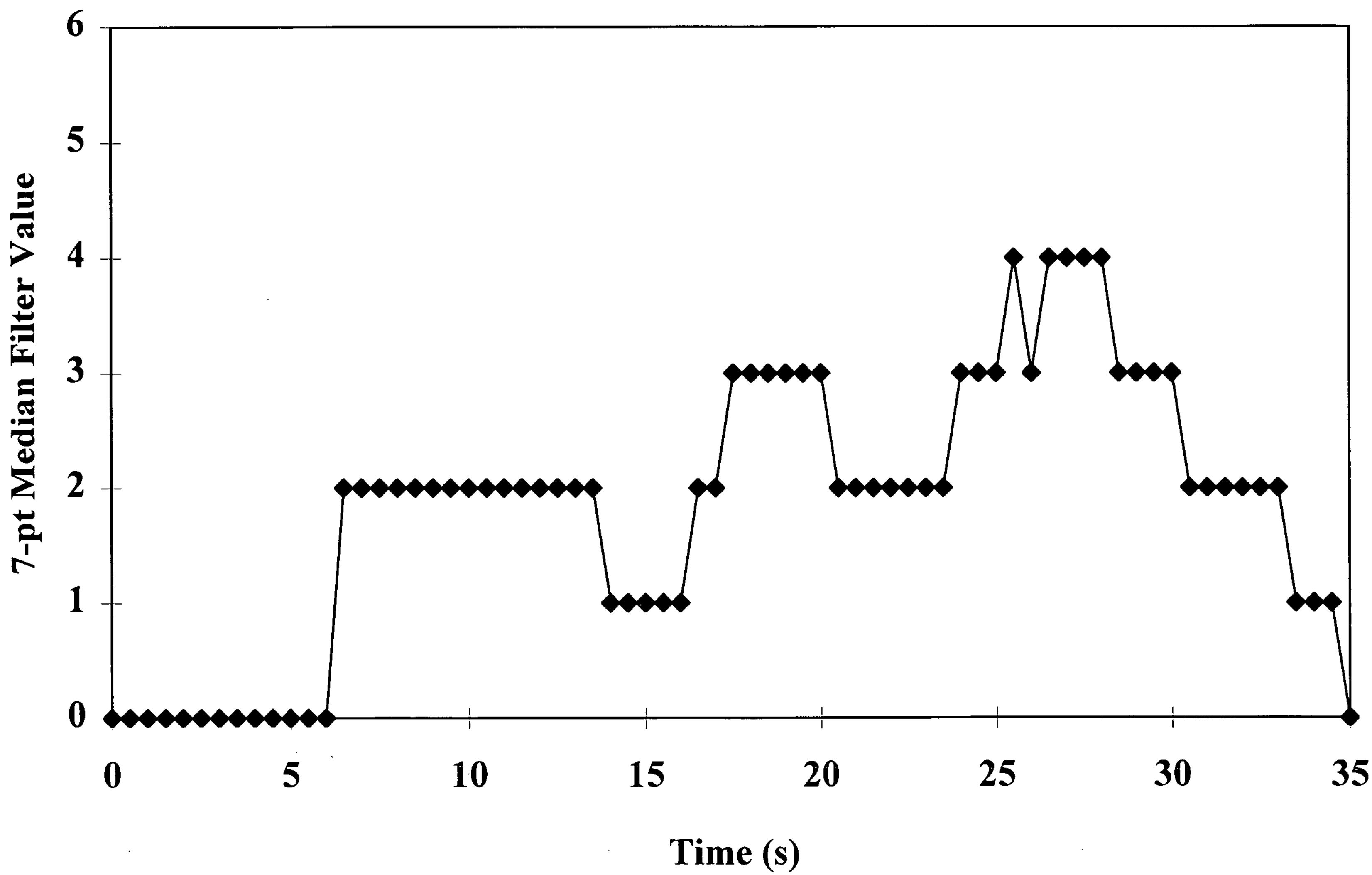
Example of a high rate of false detections filtered with a 3-point median filter (sampling rate = 2 frames per second).



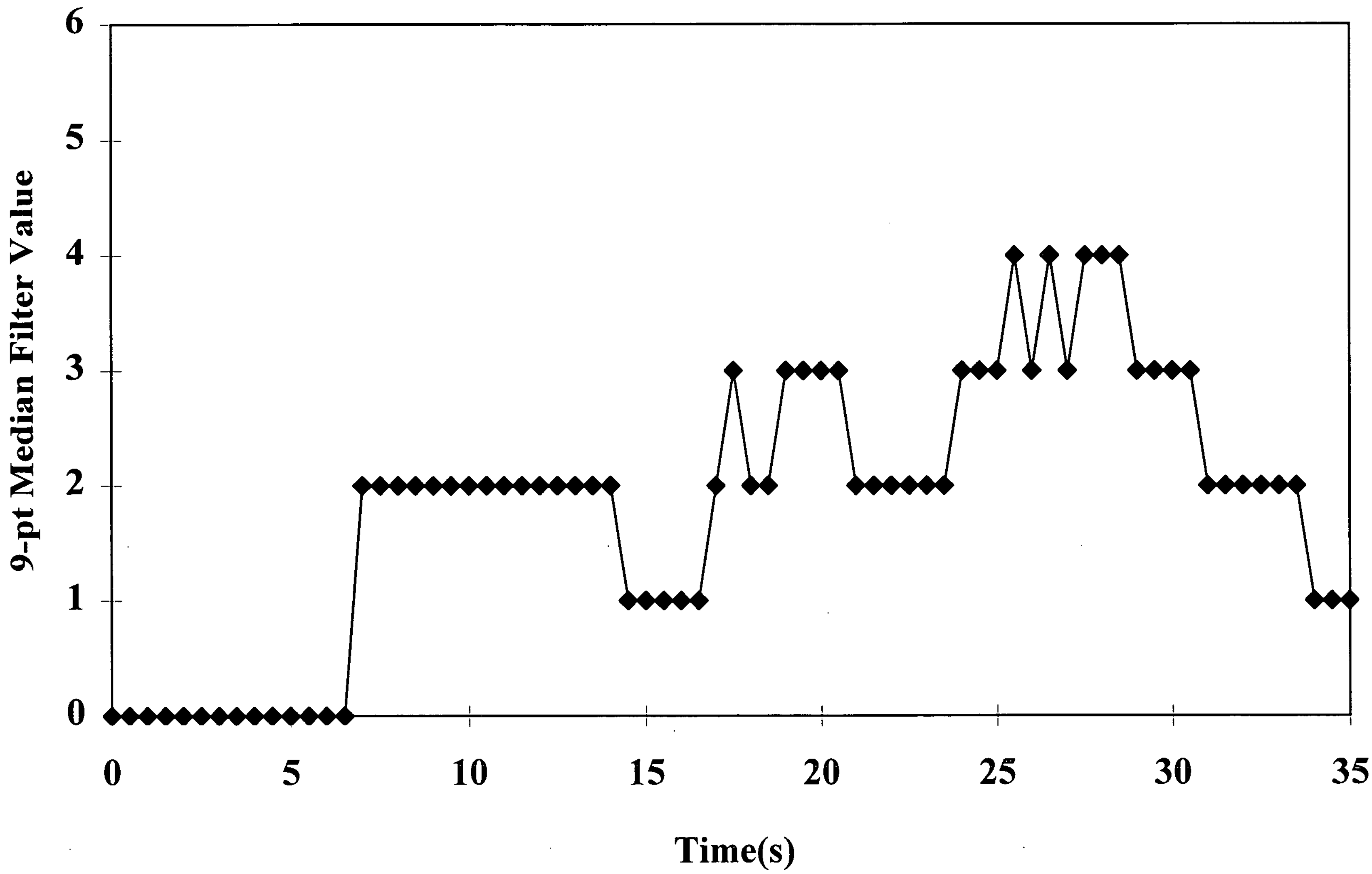
Example of a high rate of false detections filtered with a 5-point median filter (sampling rate = 2 frames per second).



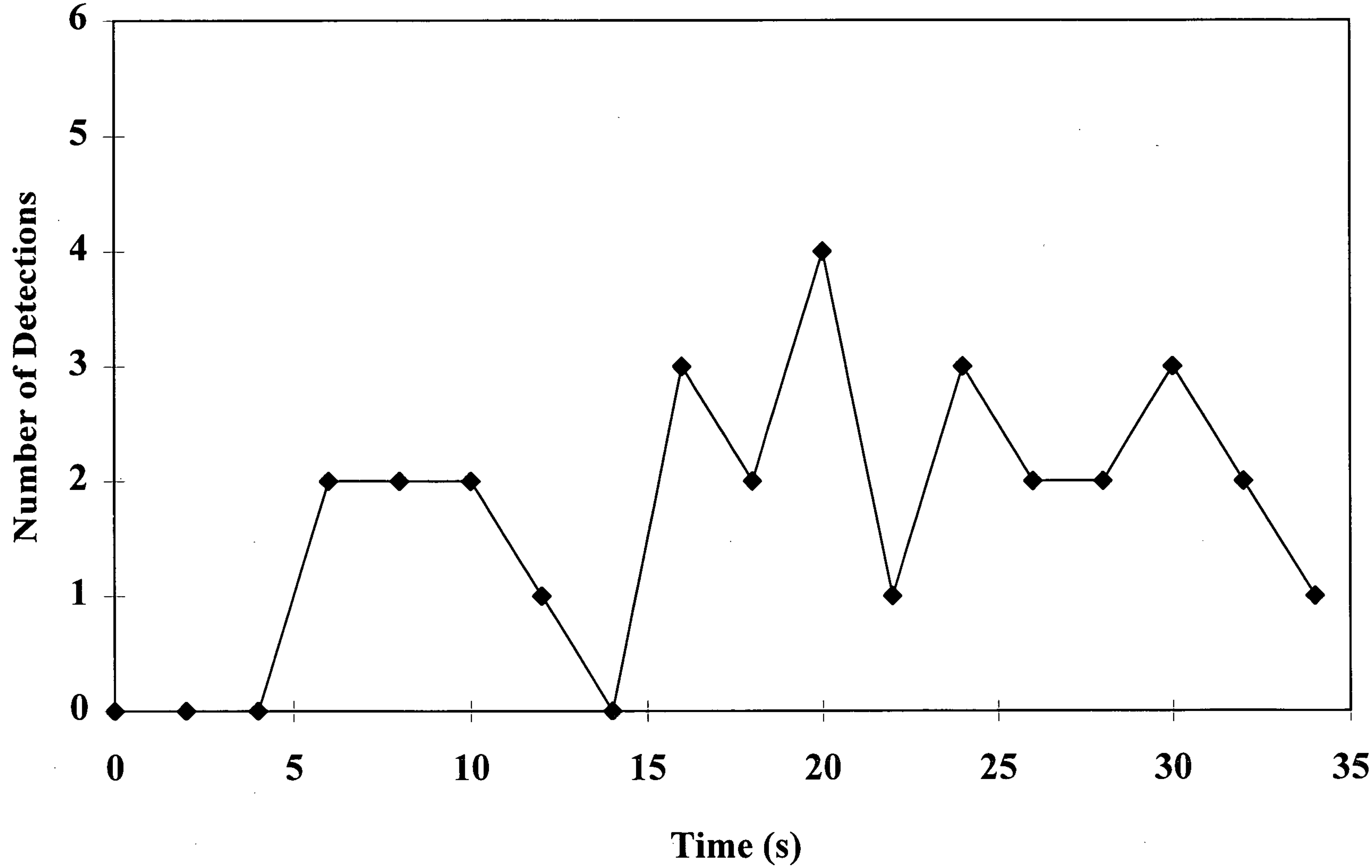
Example of a high rate of false detections filtered with a 7-point median filter (sampling rate = 2 frames per second).



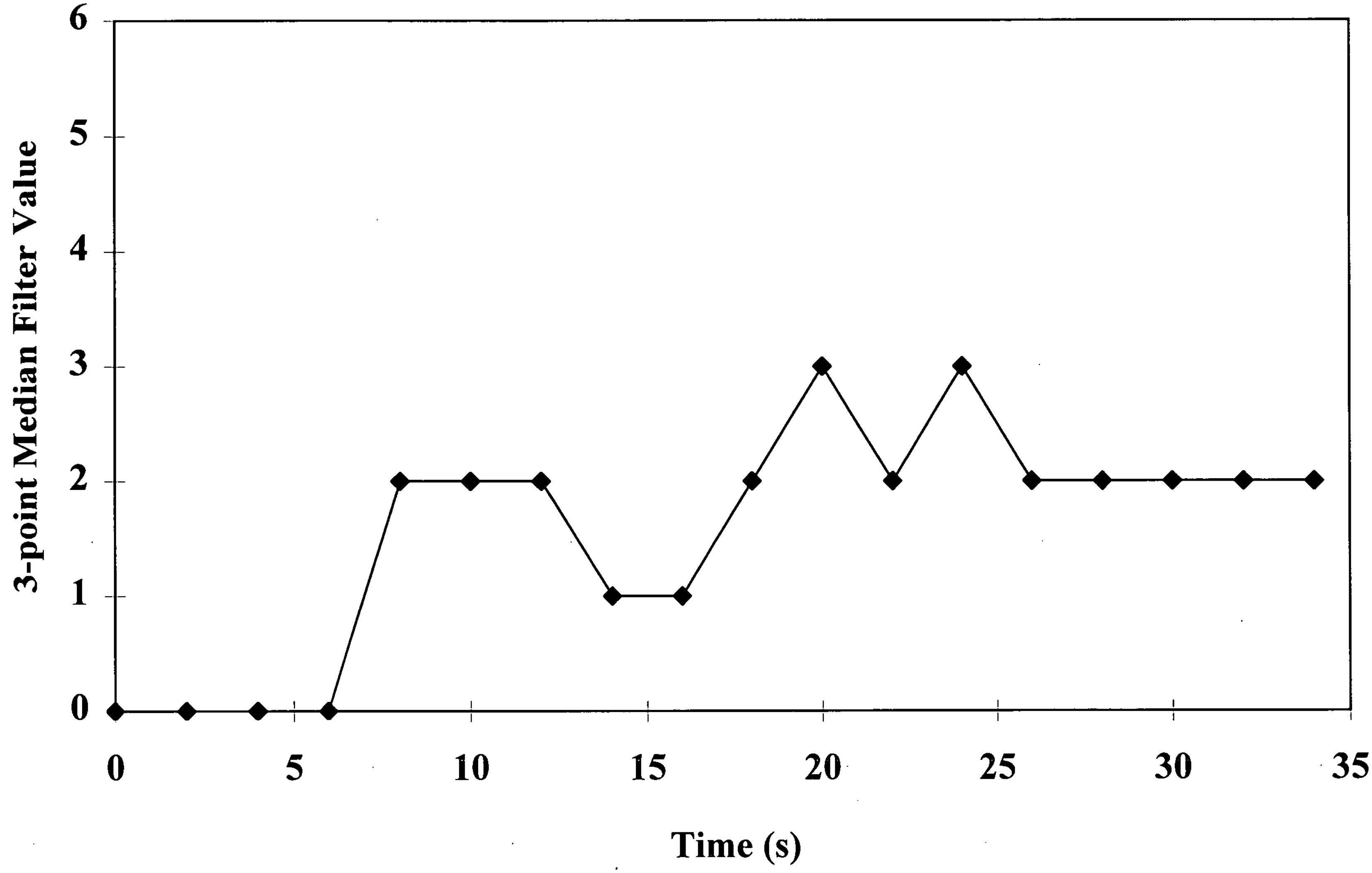
Example of a high rate of false detections filtered with a 9-point median filter (sampling rate = 2 frames per second).



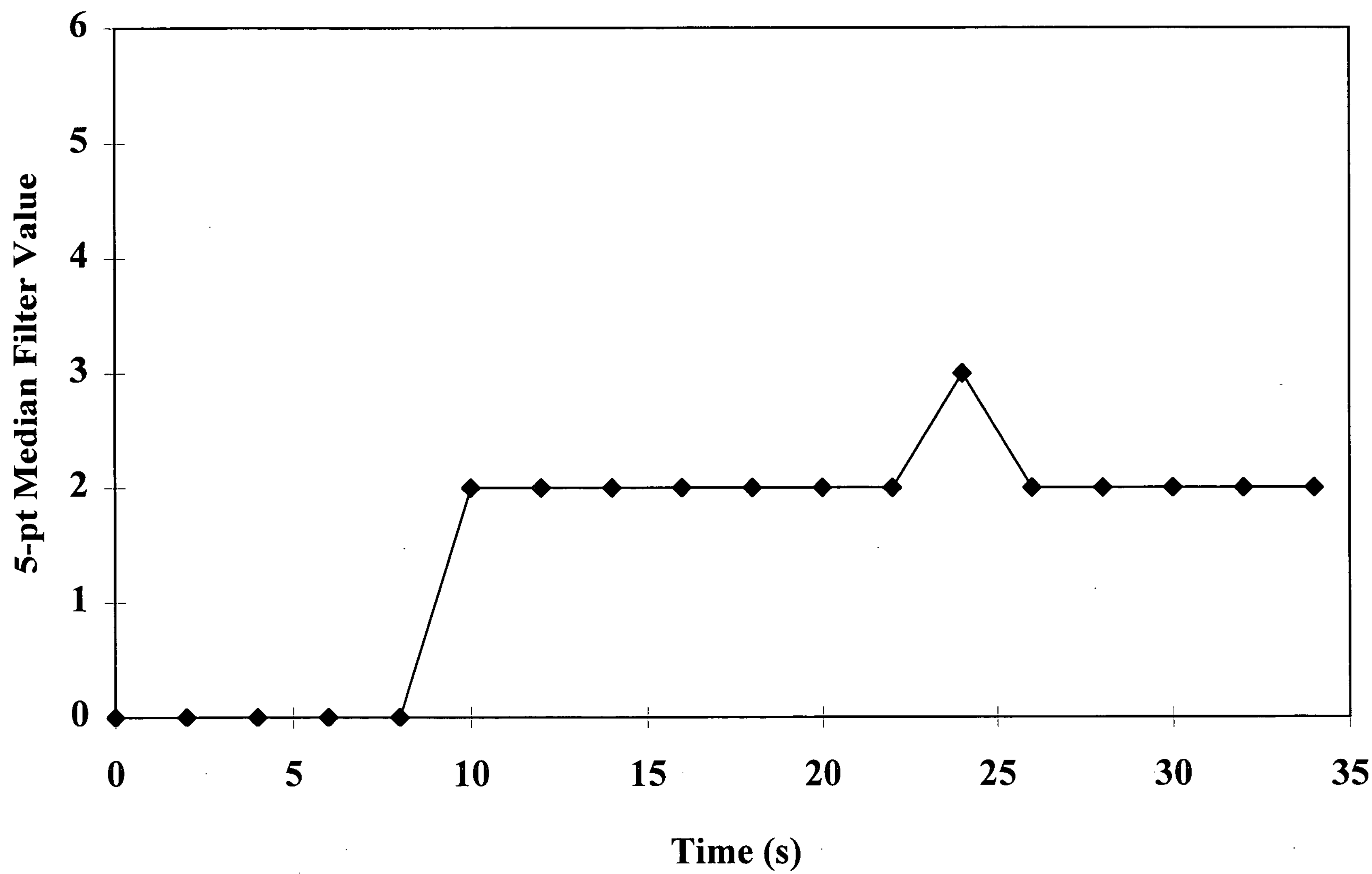
Example of a high rate of false detections (sampling rate = 0.5 frames per second).



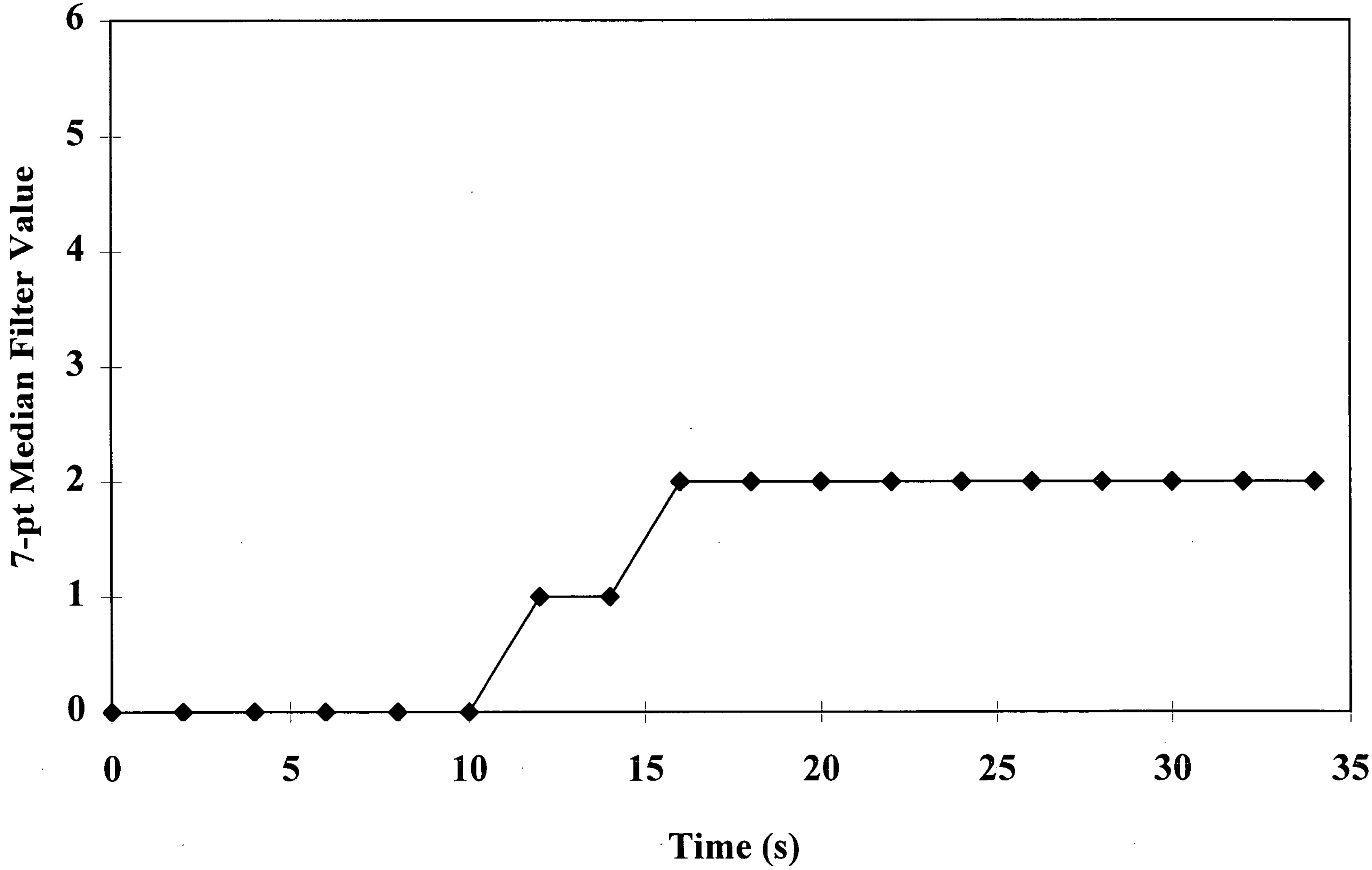
Example of a high rate of false detections filtered with a 3-point median filter (sampling rate = 0.5 frames per second).



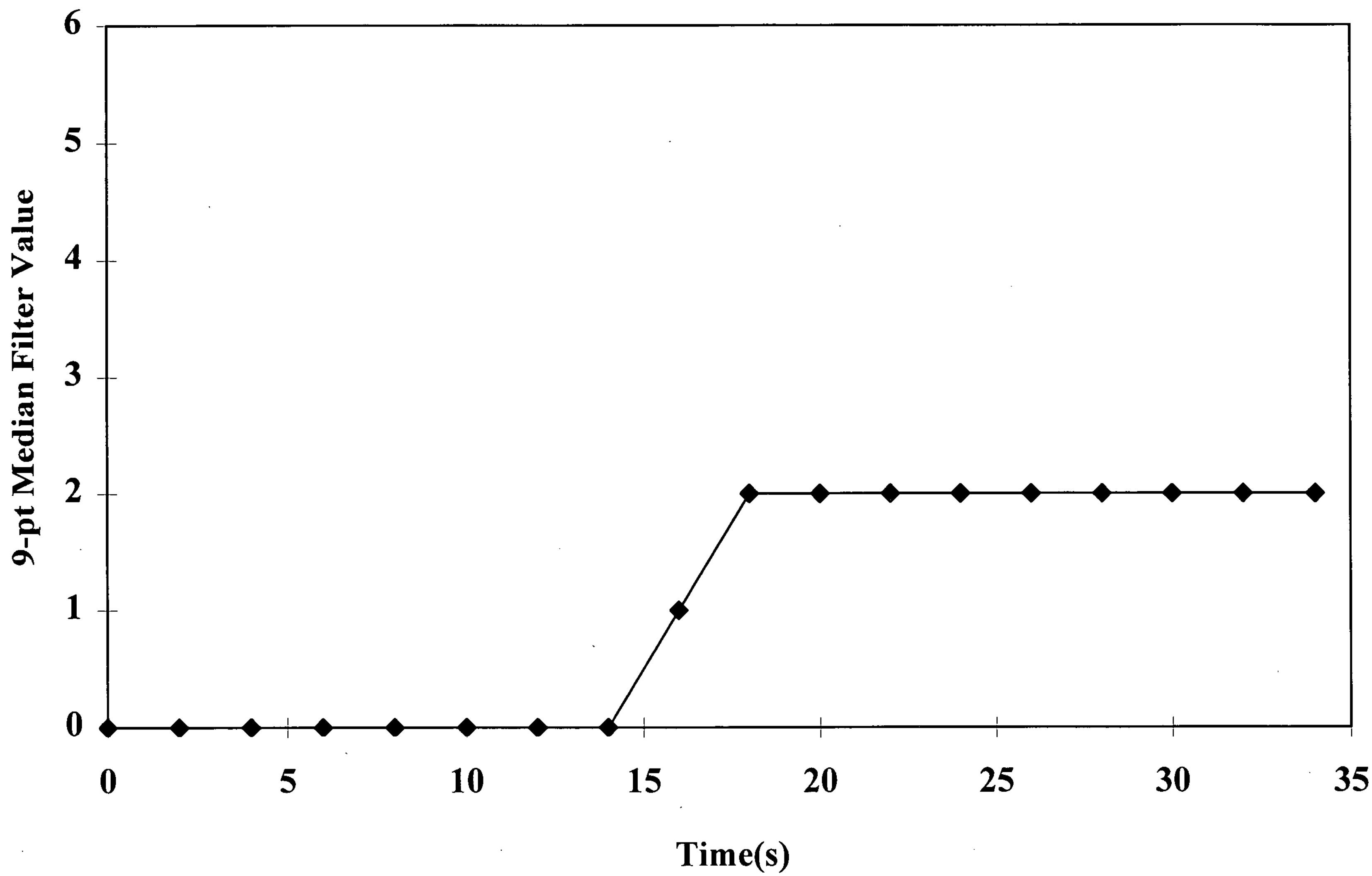
Example of a high rate of false detections filtered with a 5-point median filter (sampling rate = 0.5 frames per second).



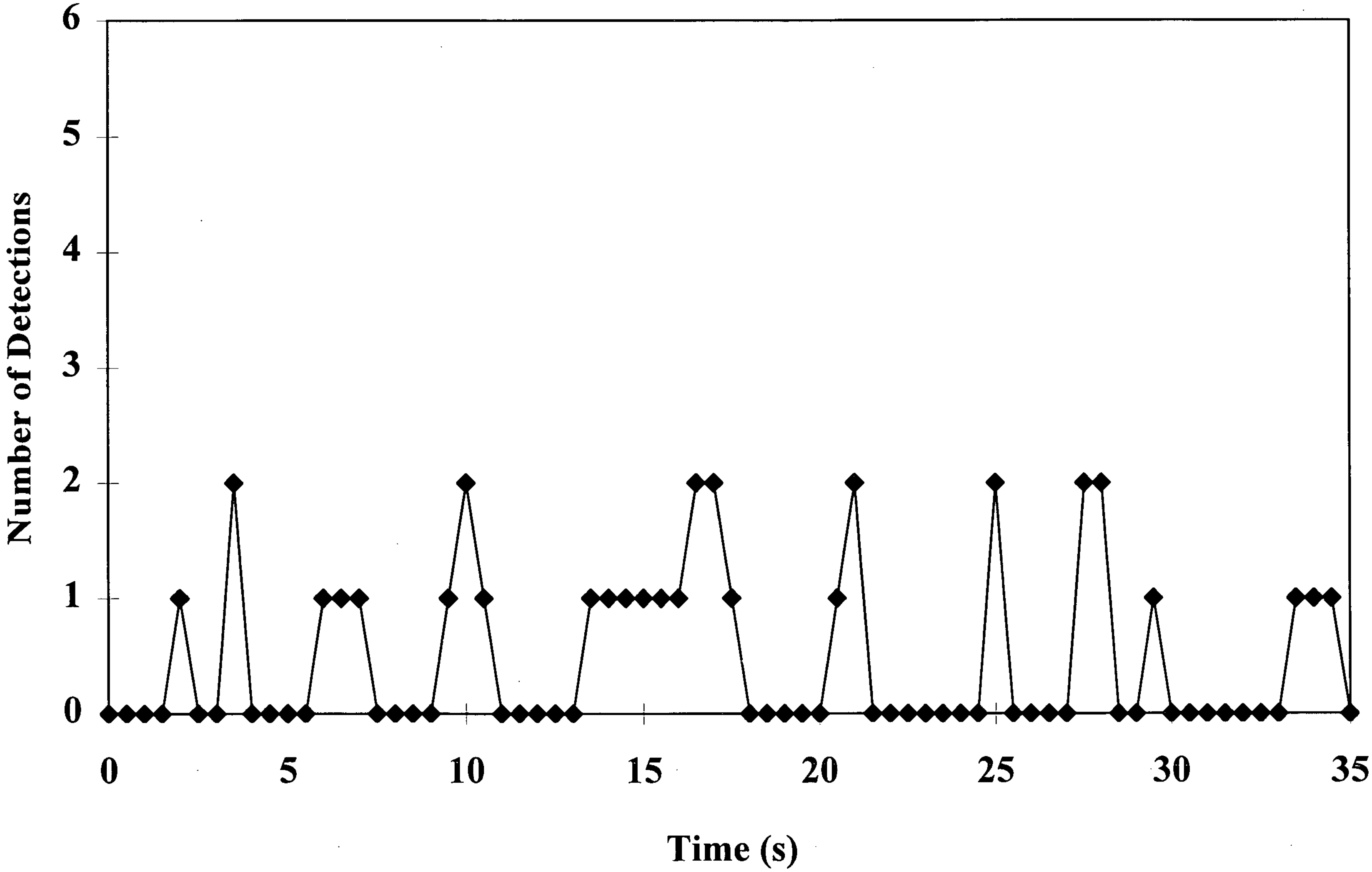
Example of a high rate of false detections filtered with a 7-point median filter (sampling rate = 0.5 frames per second).



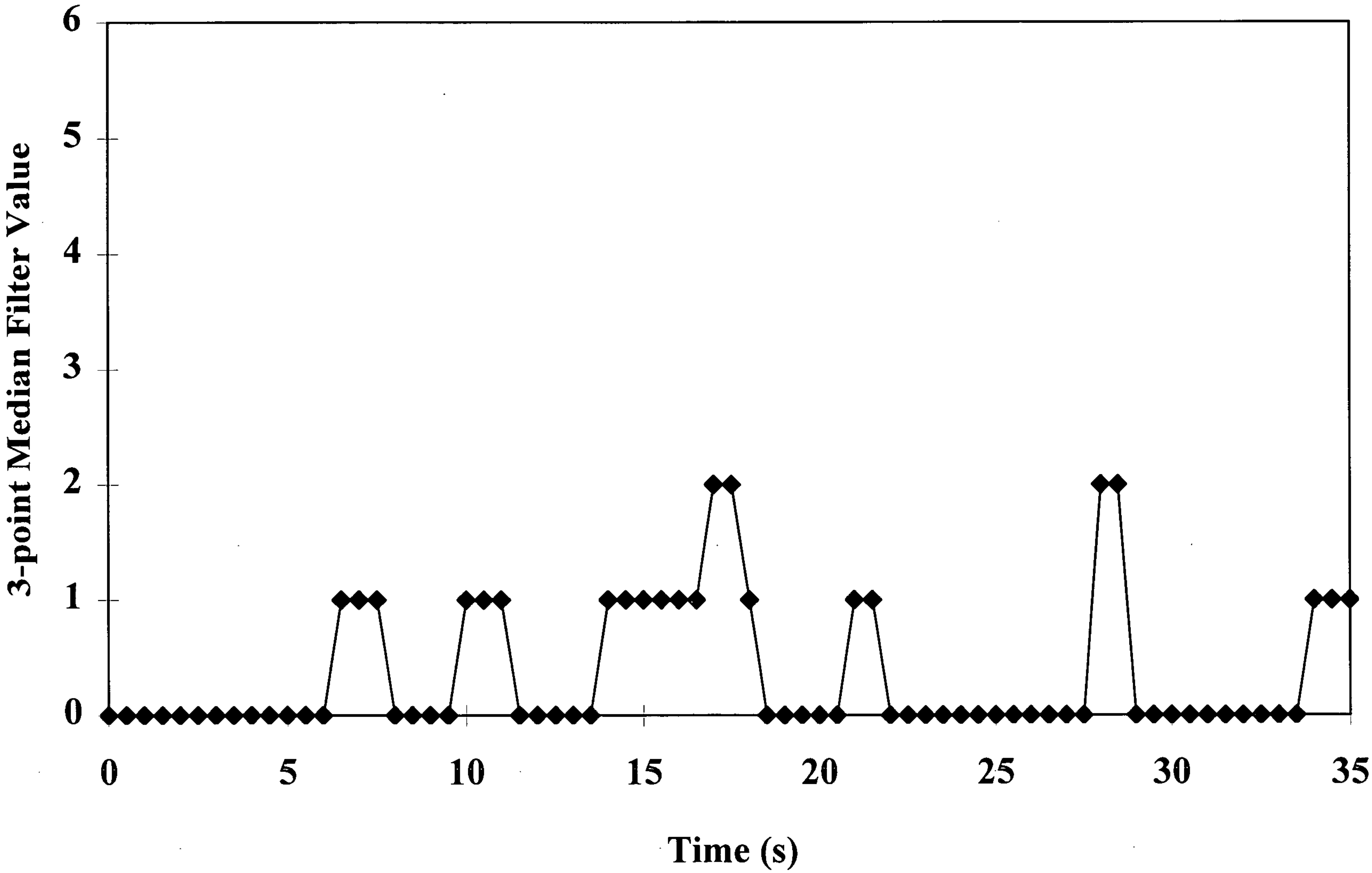
Example of a high rate of false detections filtered with a 9-point median filter (sampling rate = 0.5 frames per second).



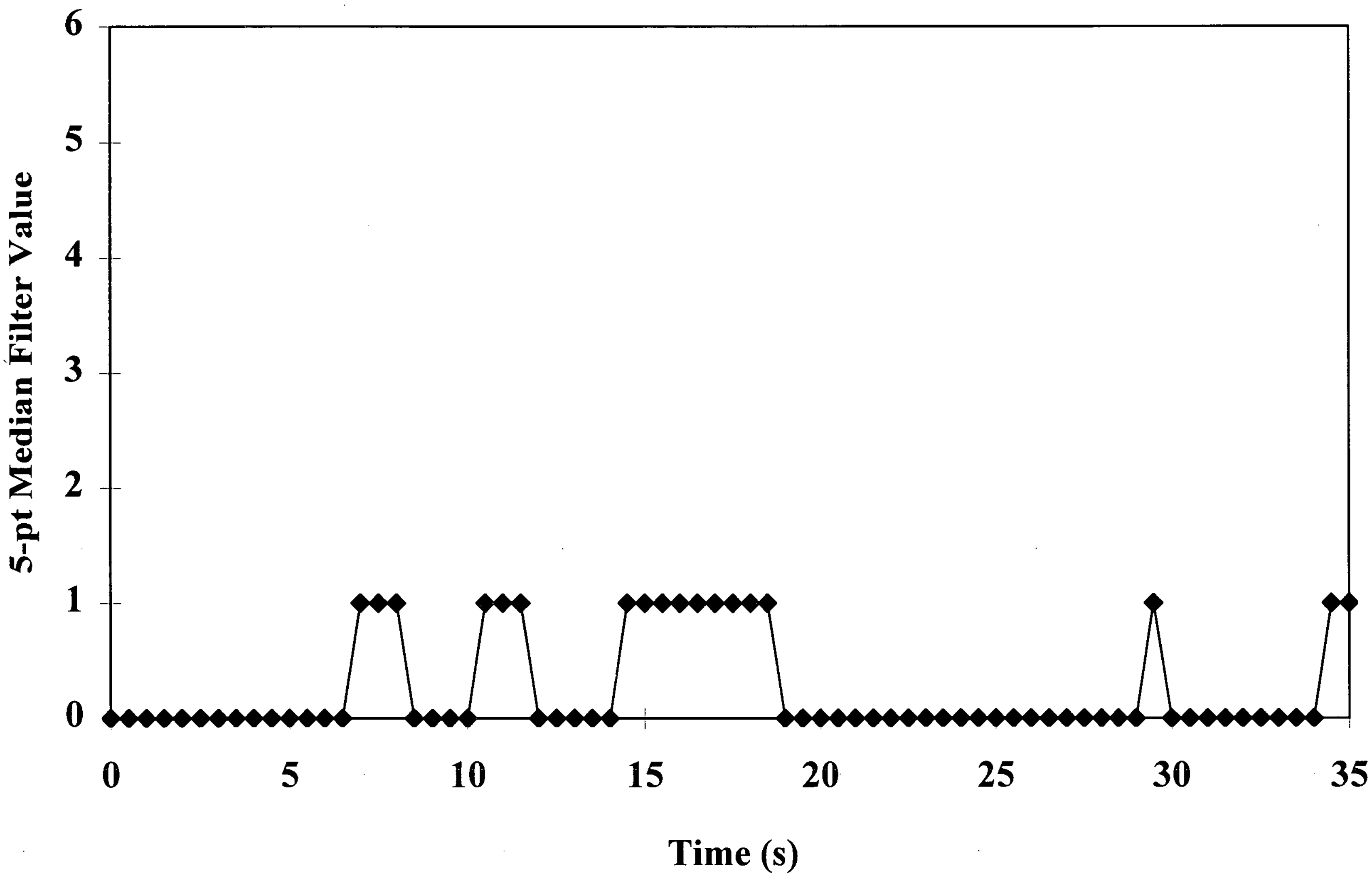
Example of typical conditions for false detections (sampling rate = 2 frames per second).



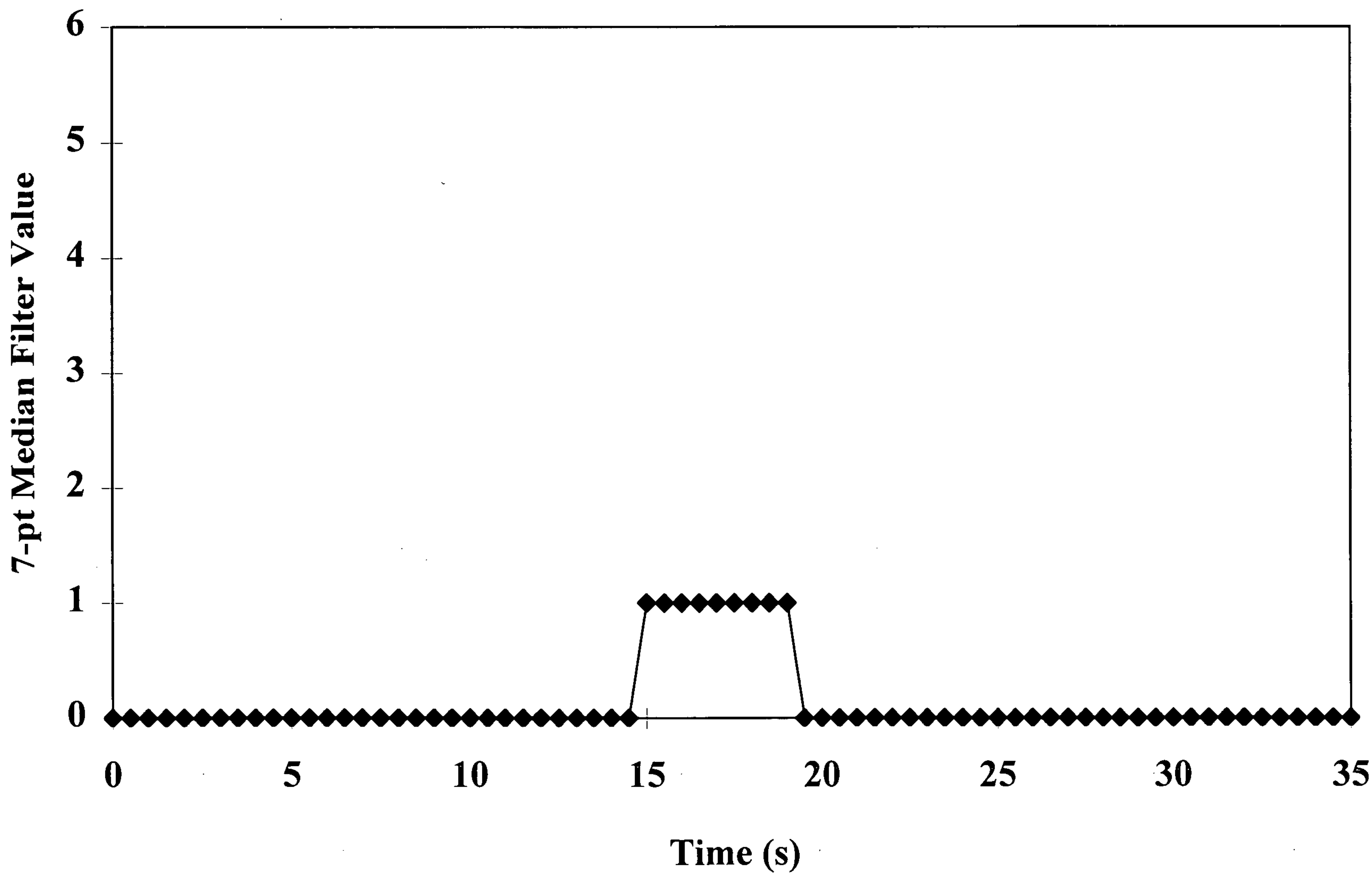
Example of typical conditions for false detections filtered with a 3-point median filter (sampling rate = 2 frames per second).



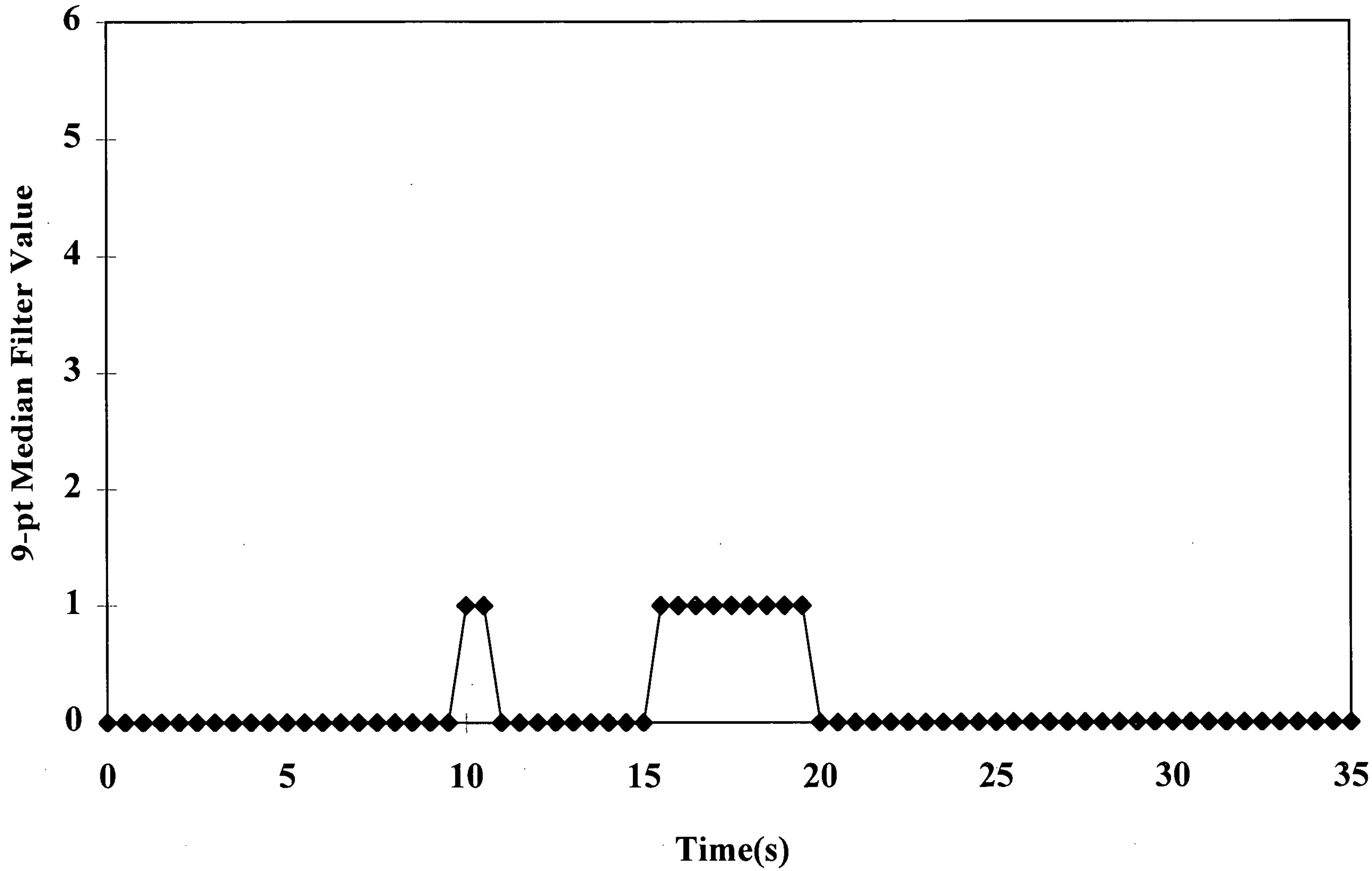
Example of typical conditions for false detections filtered with a 5-point median filter (sampling rate = 2 frames per second).



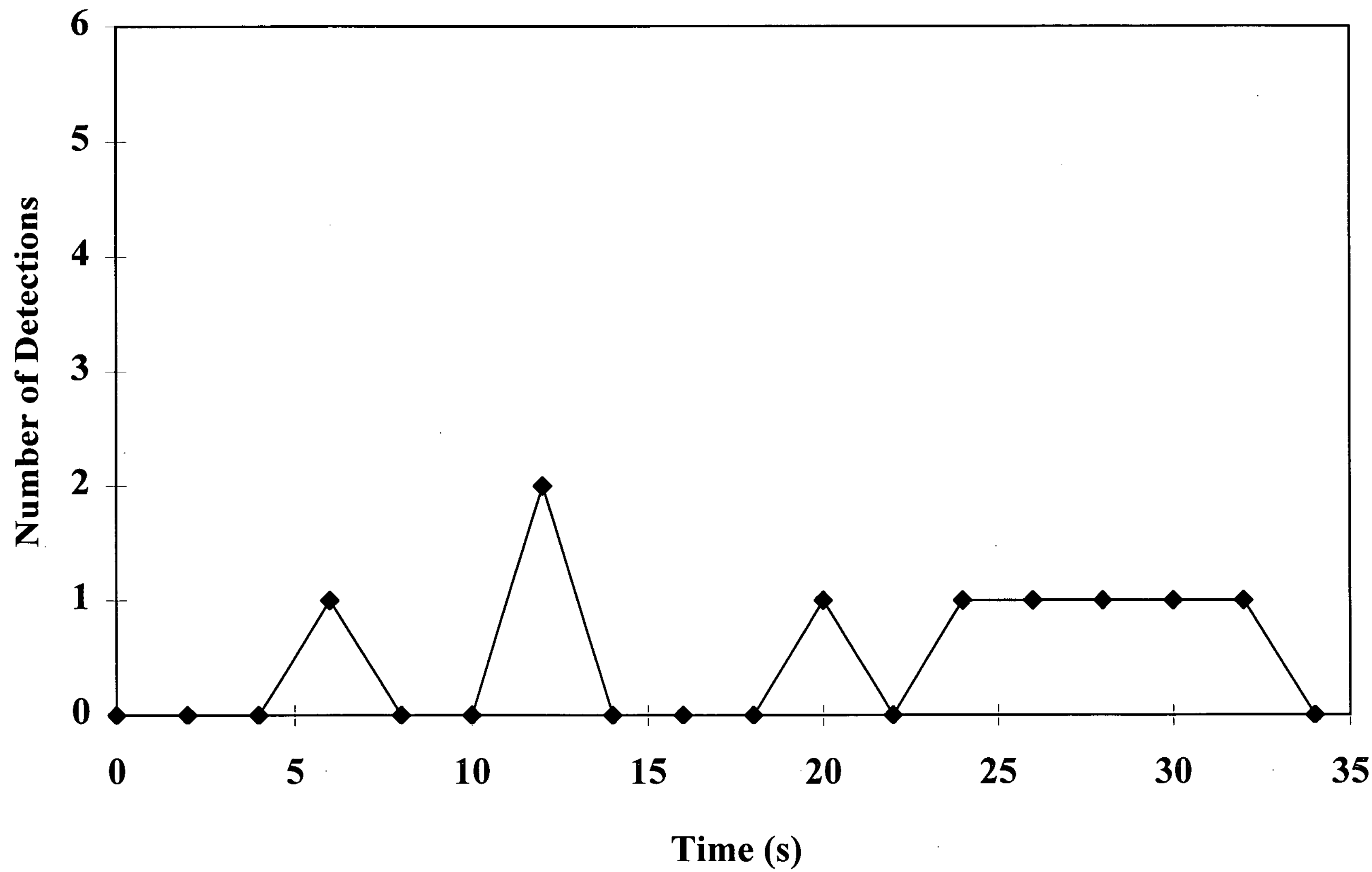
Example of typical conditions for false detections filtered with a 7-point median filter (sampling rate = 2 frames per second).



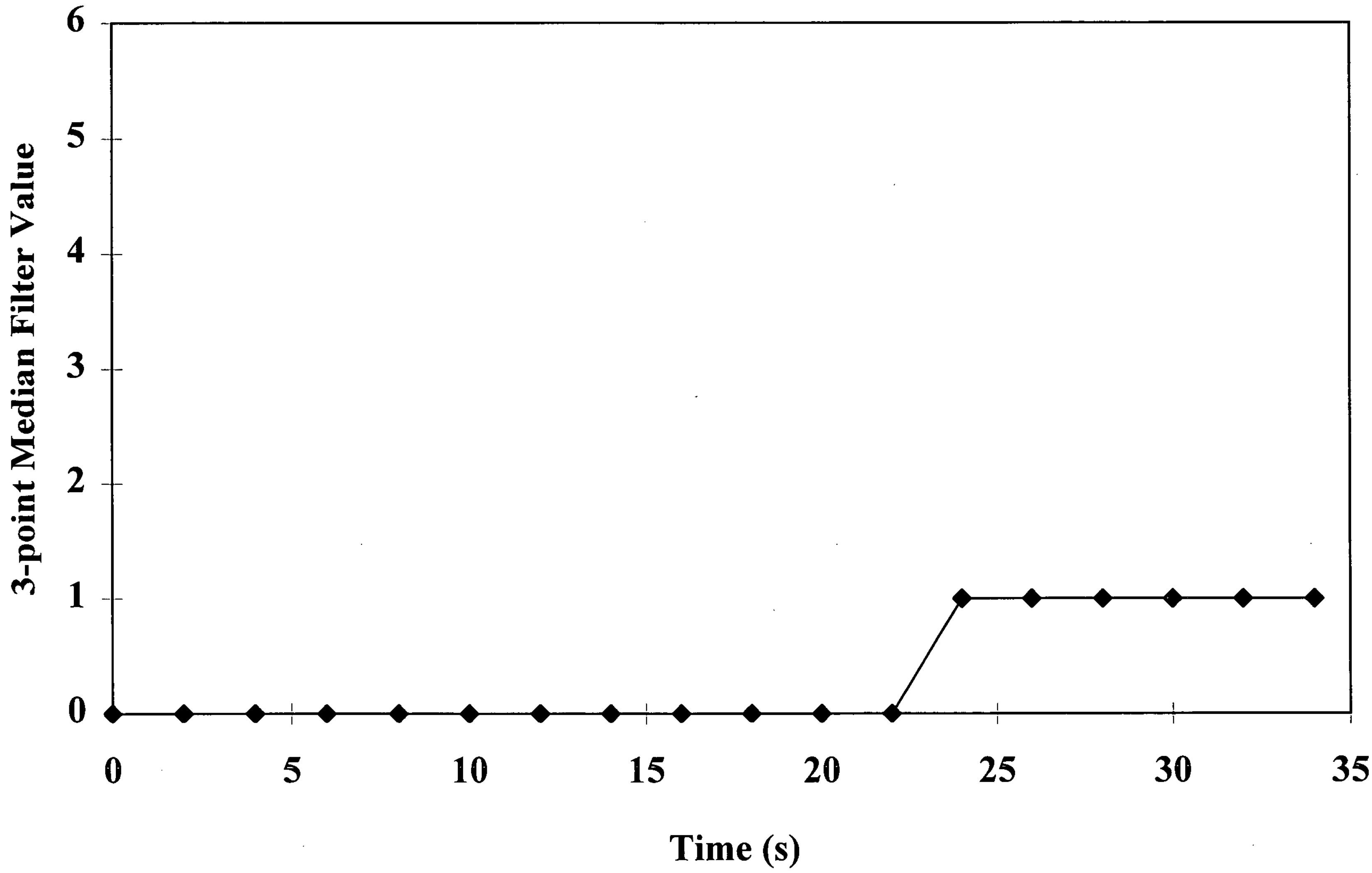
Example of typical conditions for false detections filtered with a 9-point median filter (sampling rate = 2 frames per second).



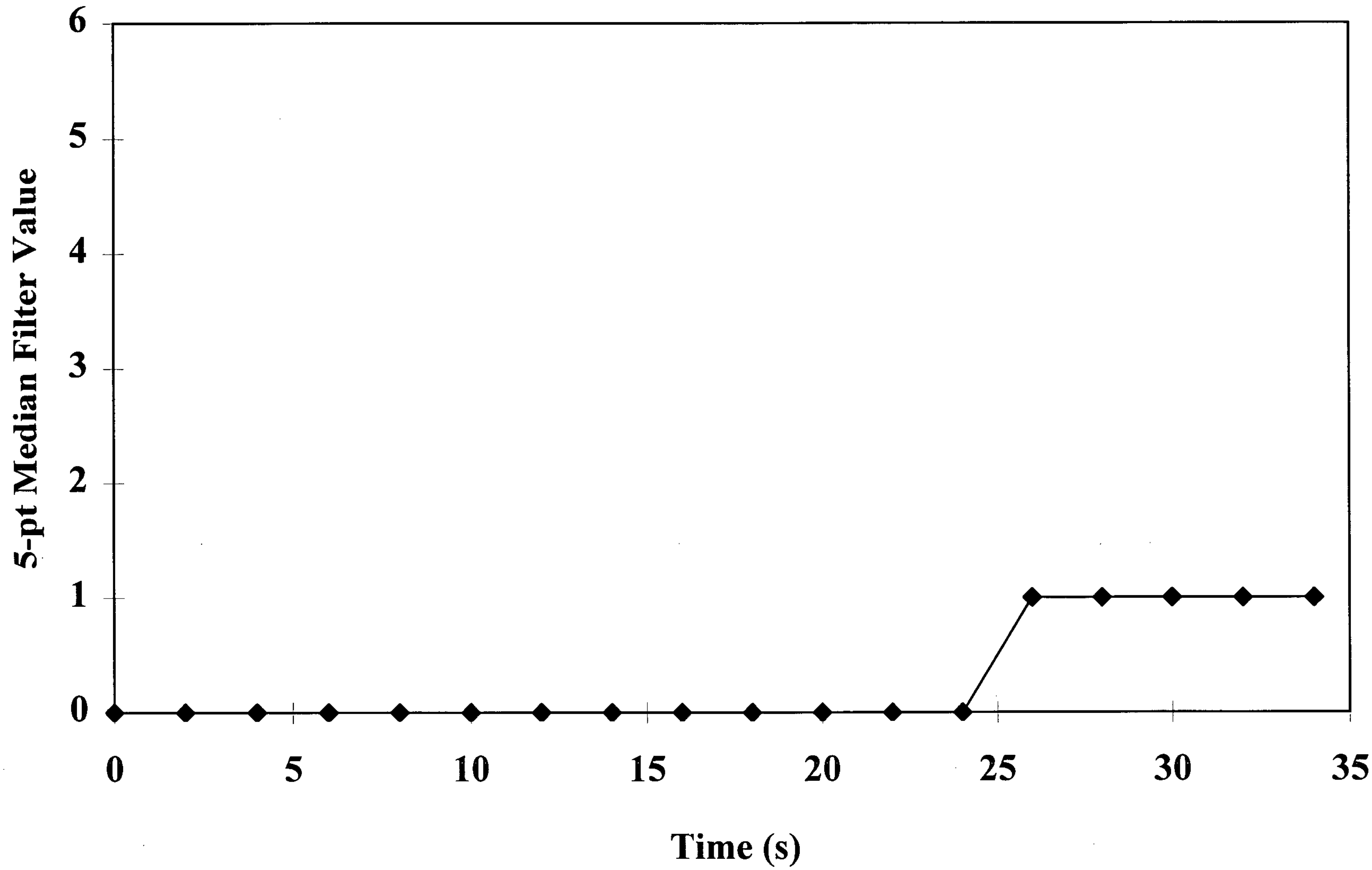
Example of typical conditions for false detections (sampling rate = 0.5 frames per second).



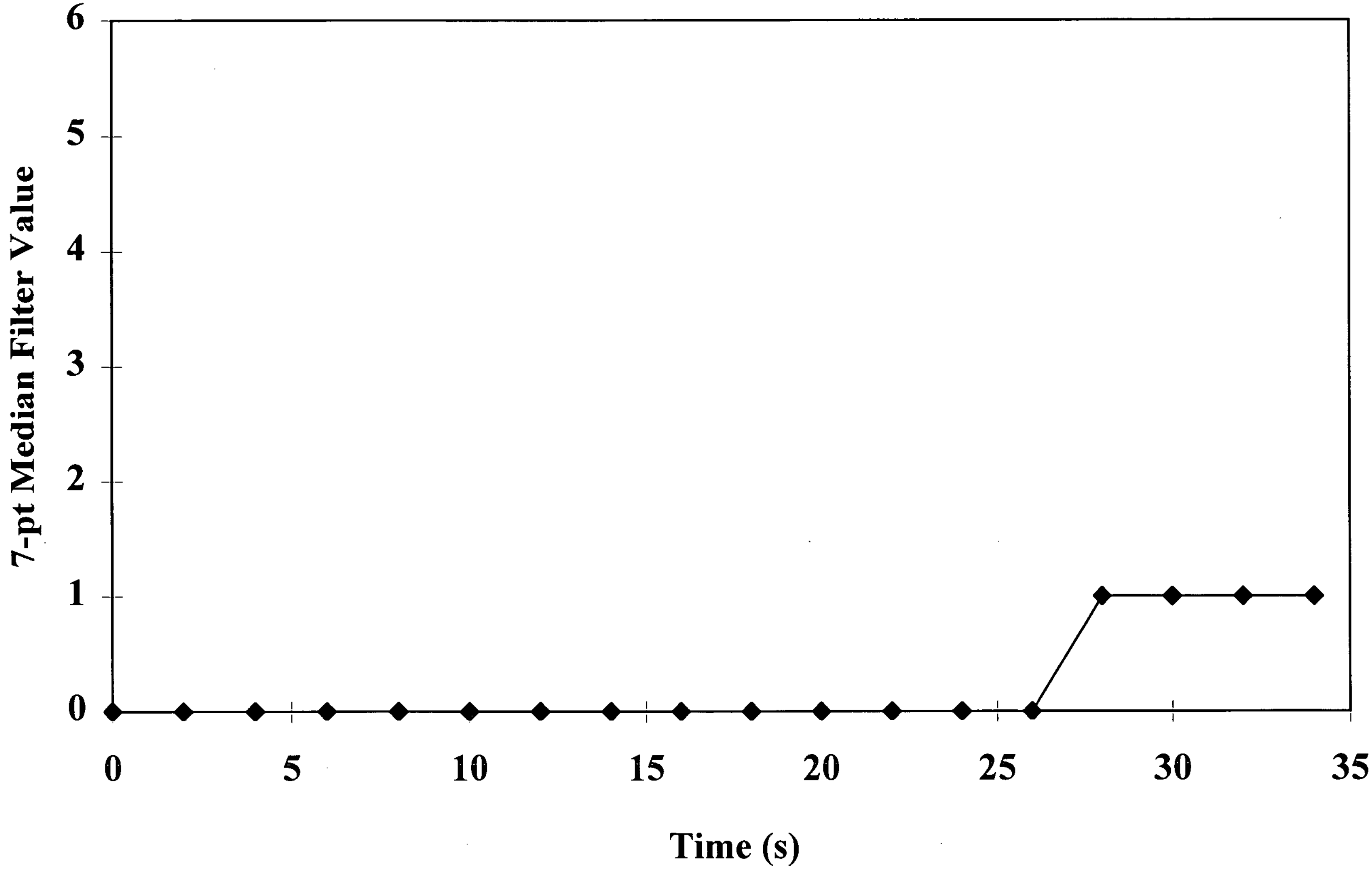
Example of typical conditions for false detections filtered with a 3-point median filter (sampling rate = 0.5 frames per second).



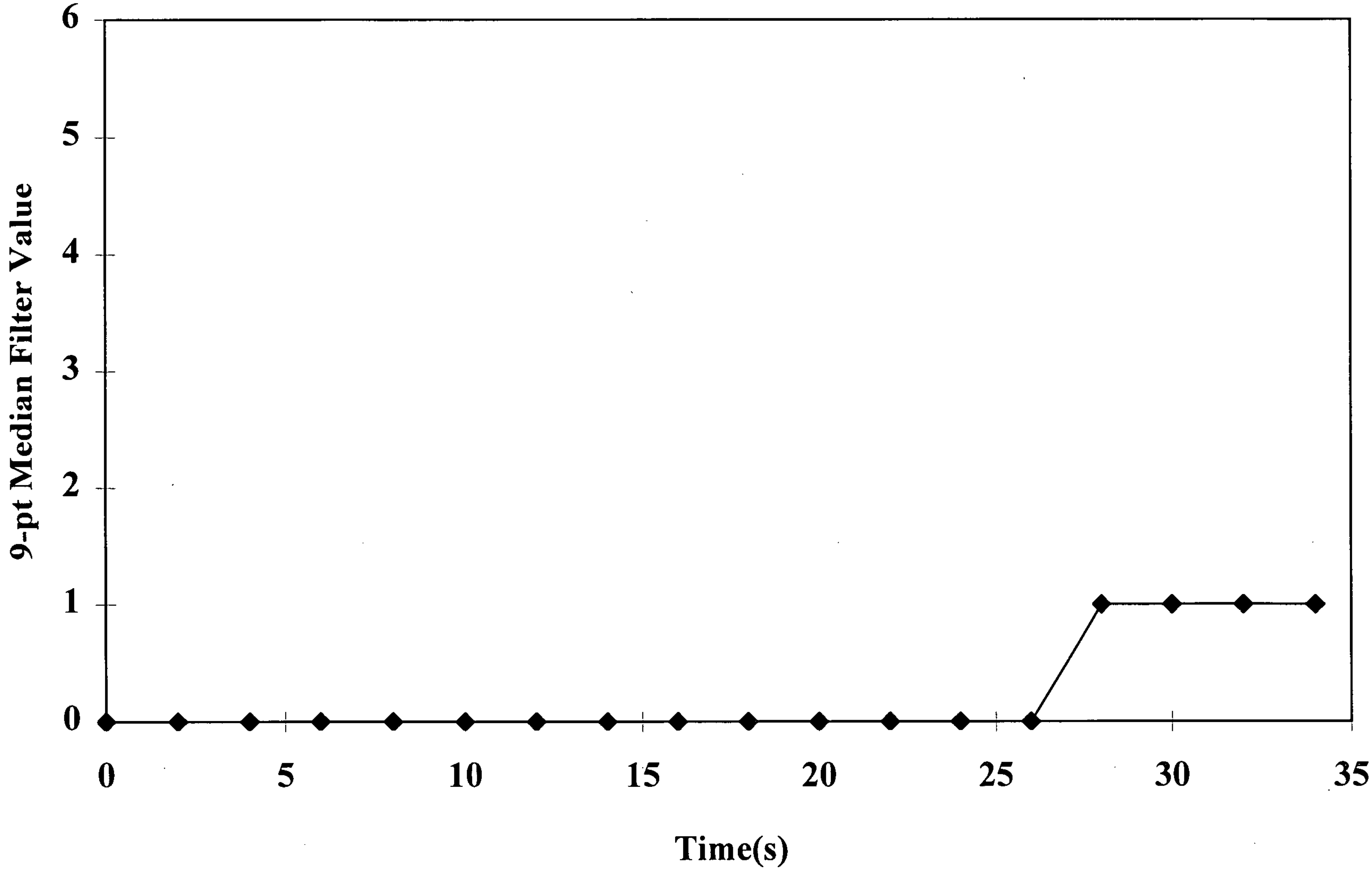
Example of typical conditions for false detections filtered with a 5-point median filter (sampling rate = 0.5 frames per second).



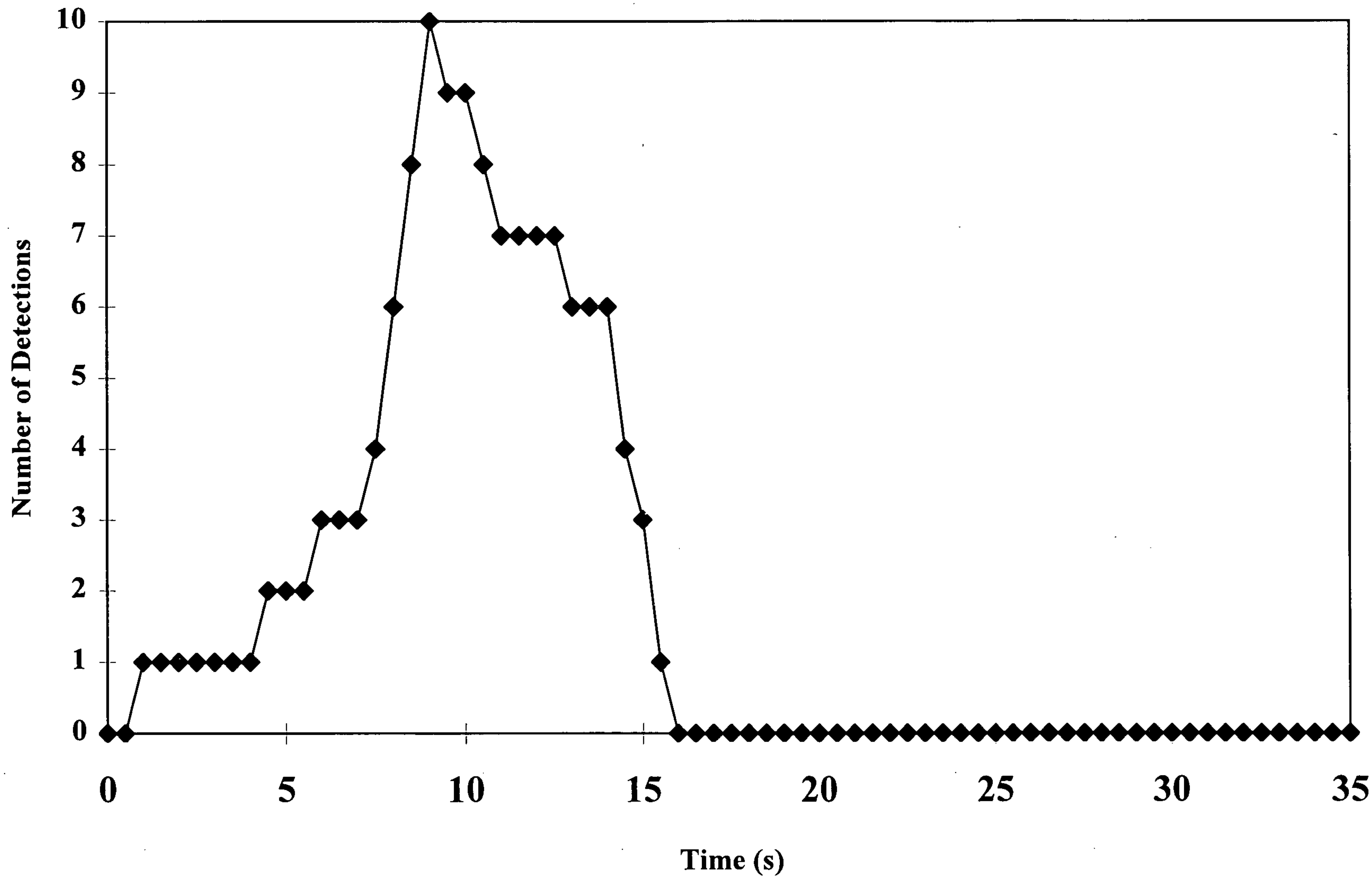
Example of typical conditions for false detections filtered with a 7-point median filter (sampling rate = 0.5 frames per second).



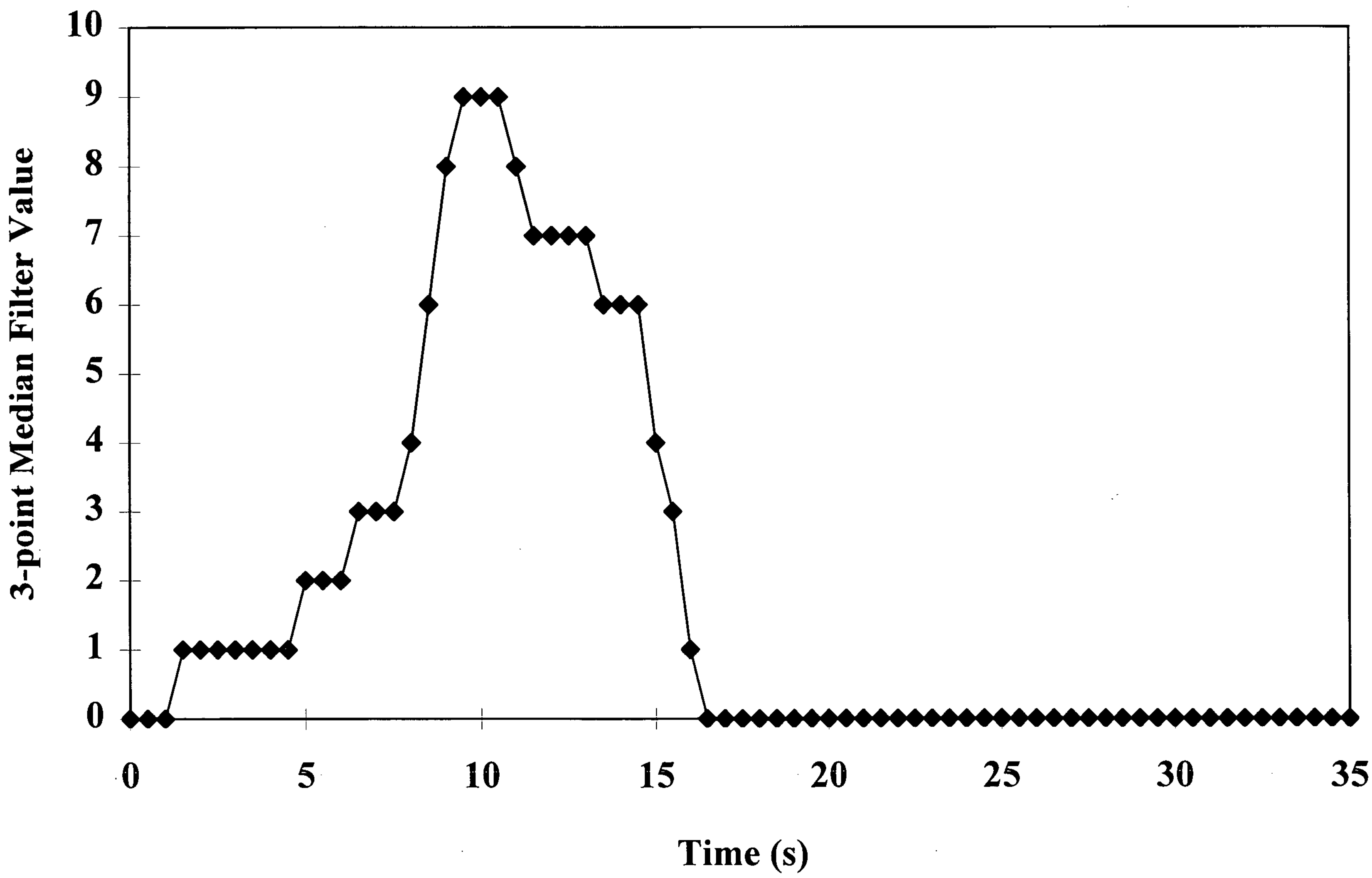
Example of typical conditions for false detections filtered with a 9-point median filter (sampling rate = 0.5 frames per second).



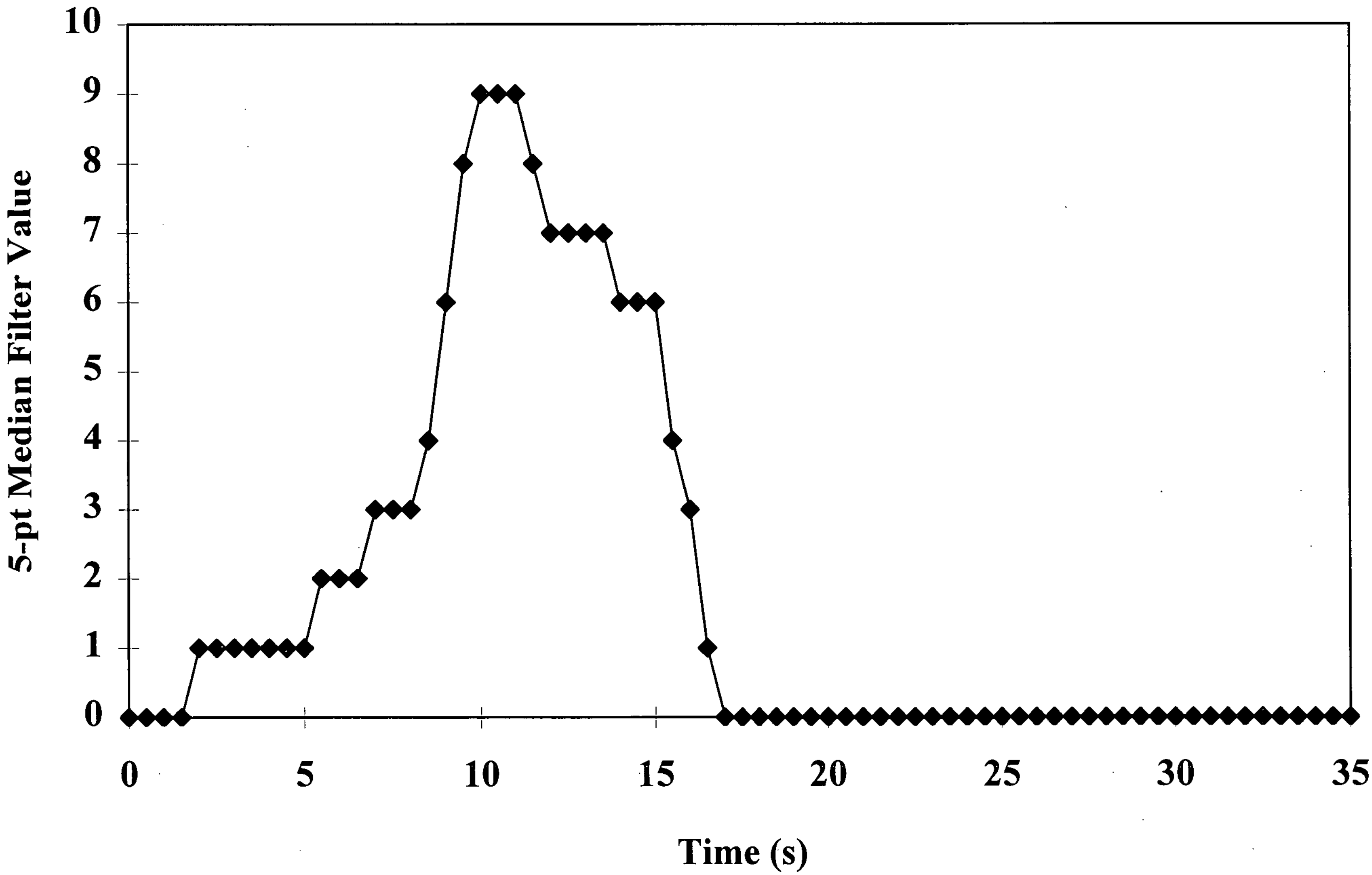
Example of a burst pellet event (sampling rate = 2 frames per second).



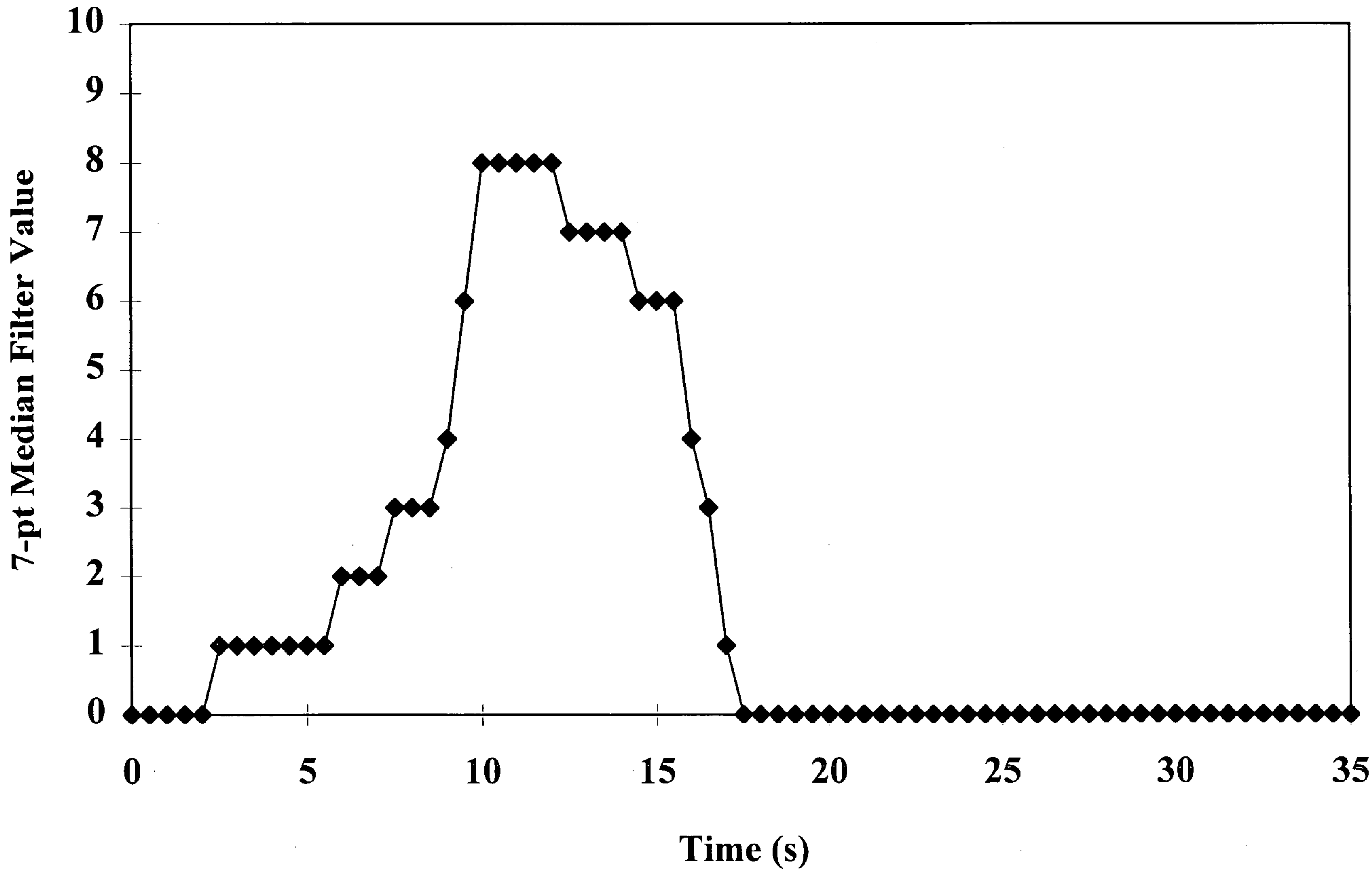
Example of a burst pellet event filtered with a 3-point median filter (sampling rate = 2 frames per second).



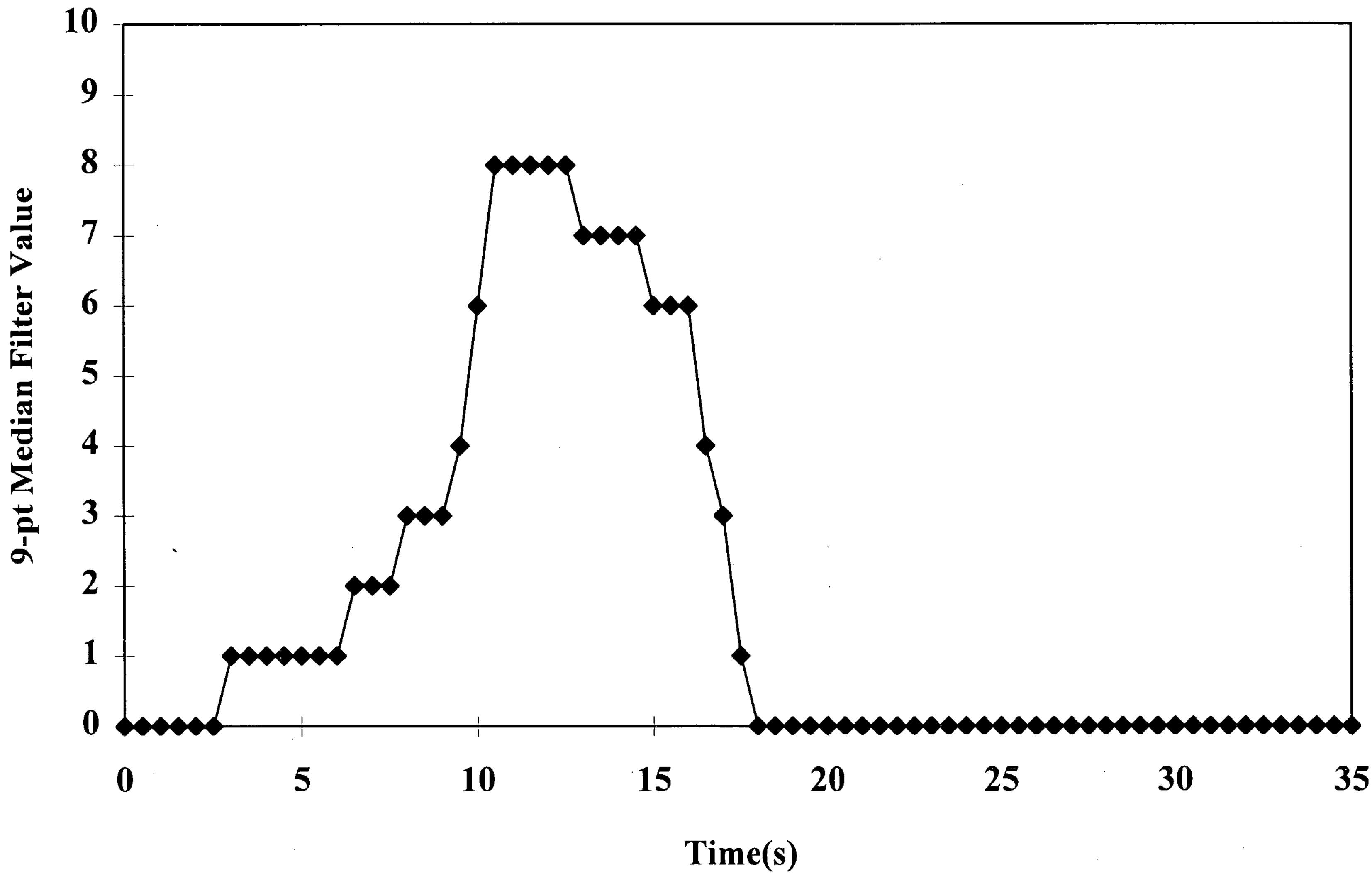
Example of a burst pellet event filtered with a 5-point median filter (sampling rate = 2 frames per second).



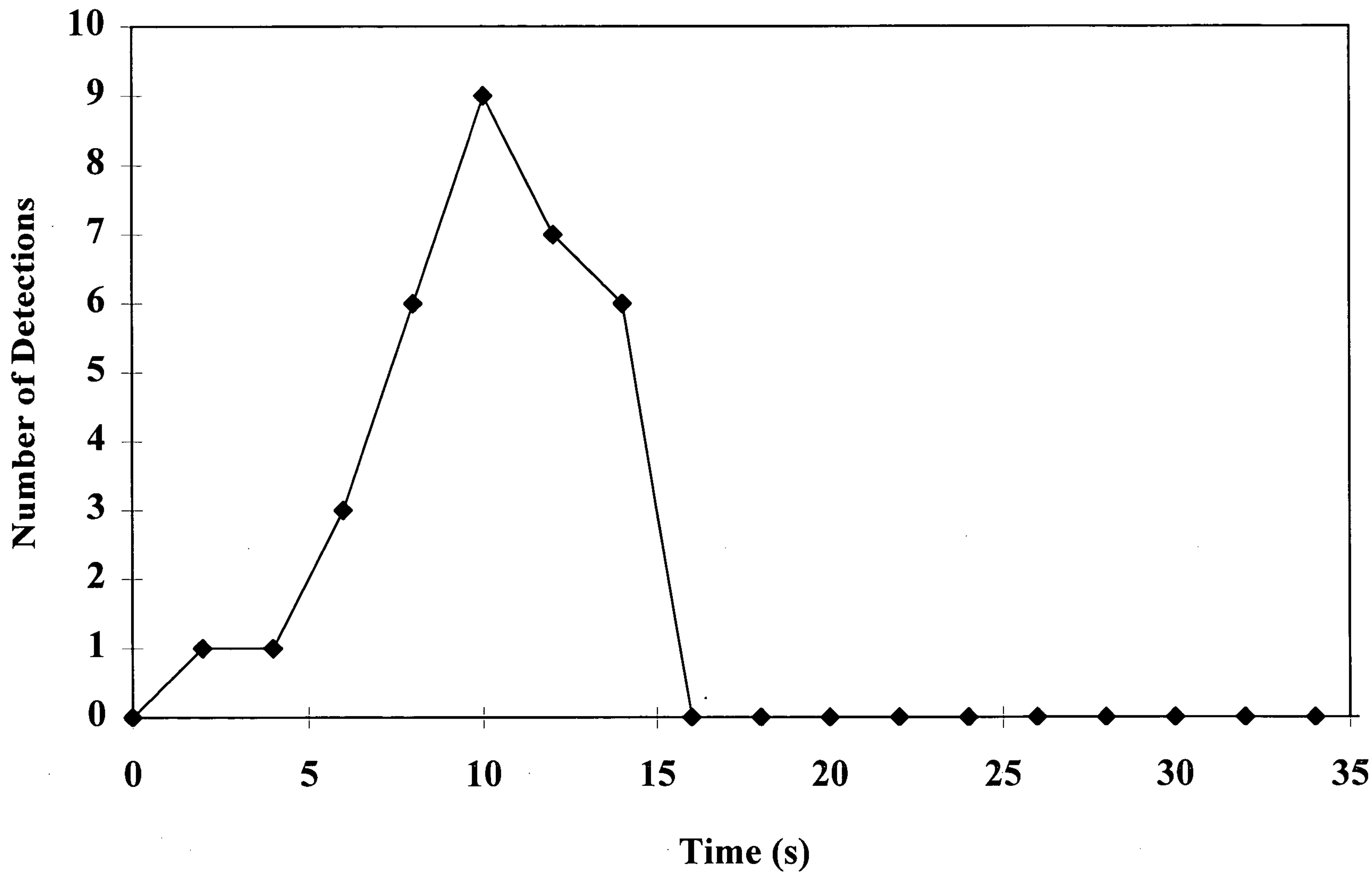
Example of a burst pellet event filtered with a 7-point median filter (sampling rate = 2 frames per second).



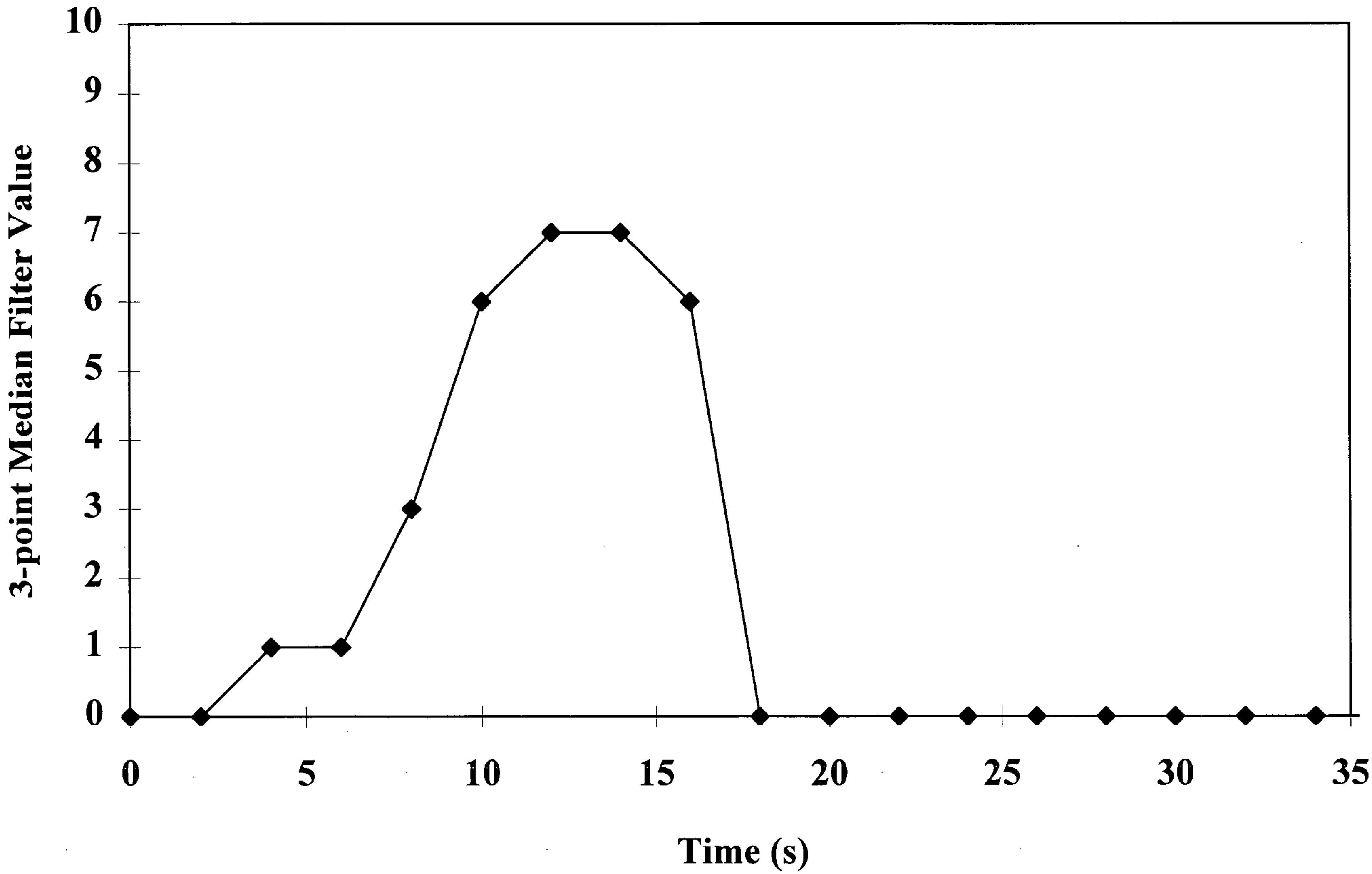
Example of a burst pellet event filtered with a 9-point median filter (sampling rate = 2 frames per second).



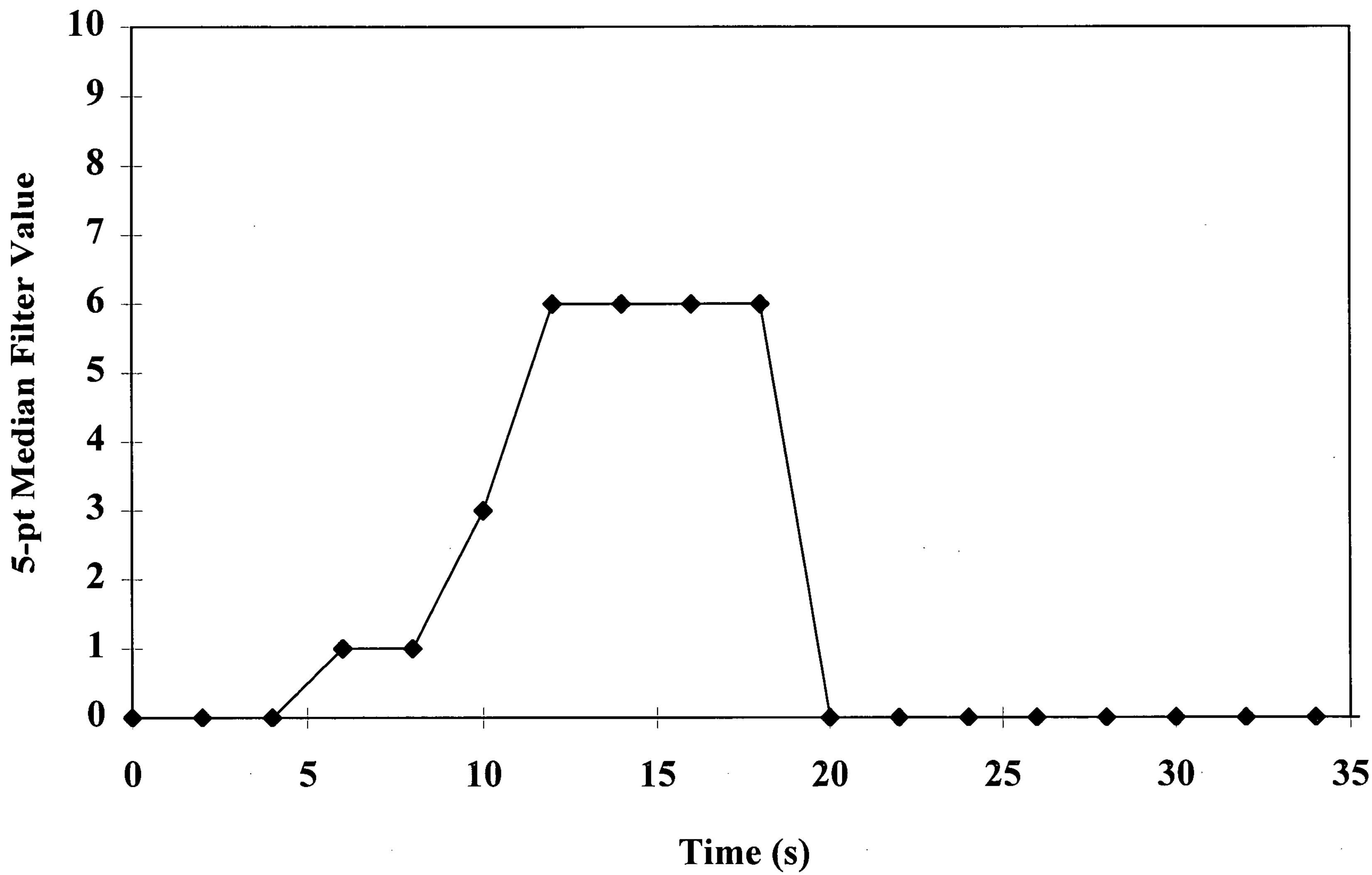
Example of a burst pellet event (sampling rate = 0.5 frames per second).



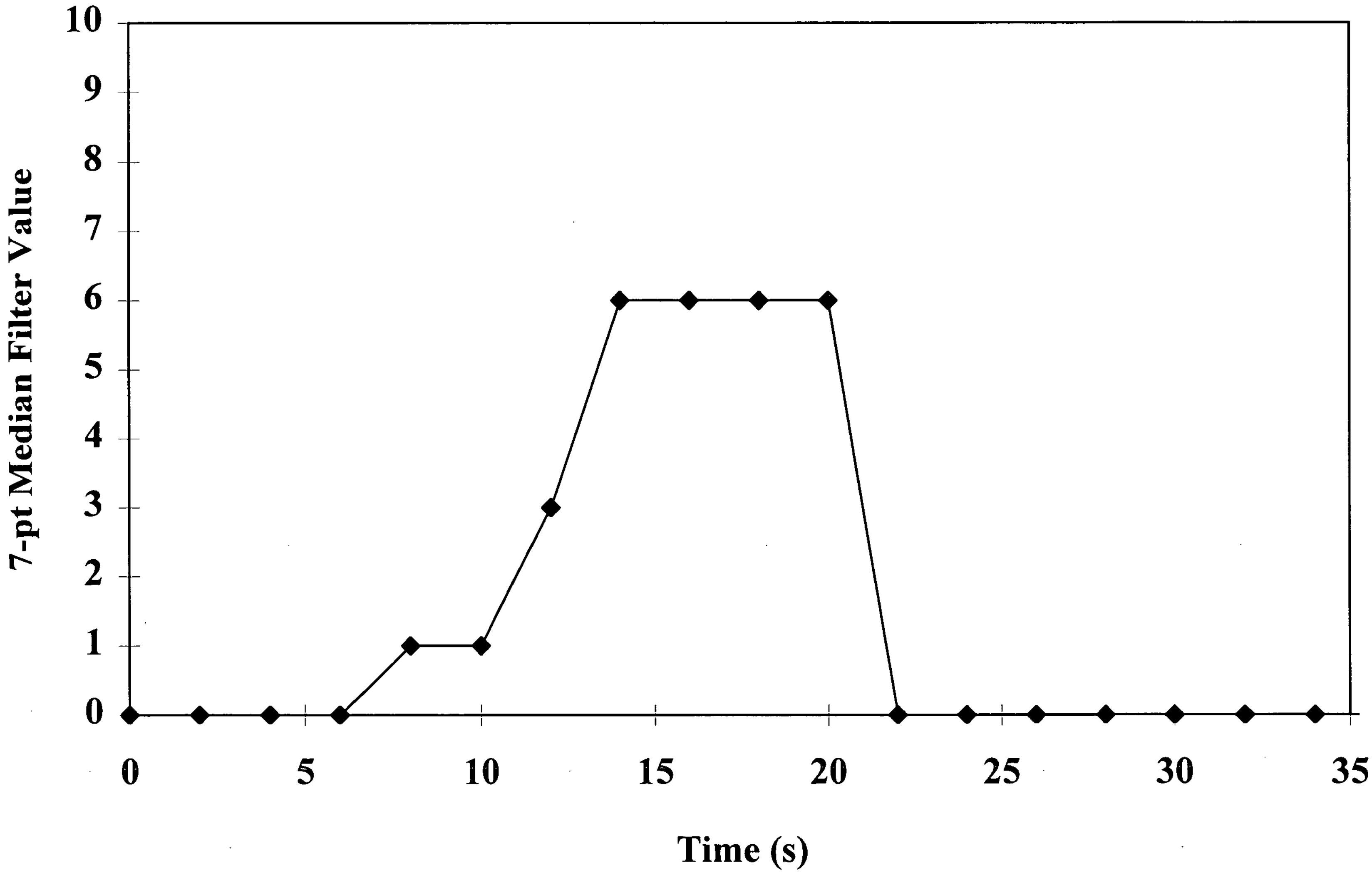
Example of a burst pellet event filtered with a 3-point median filter (sampling rate = 0.5 frames per second).



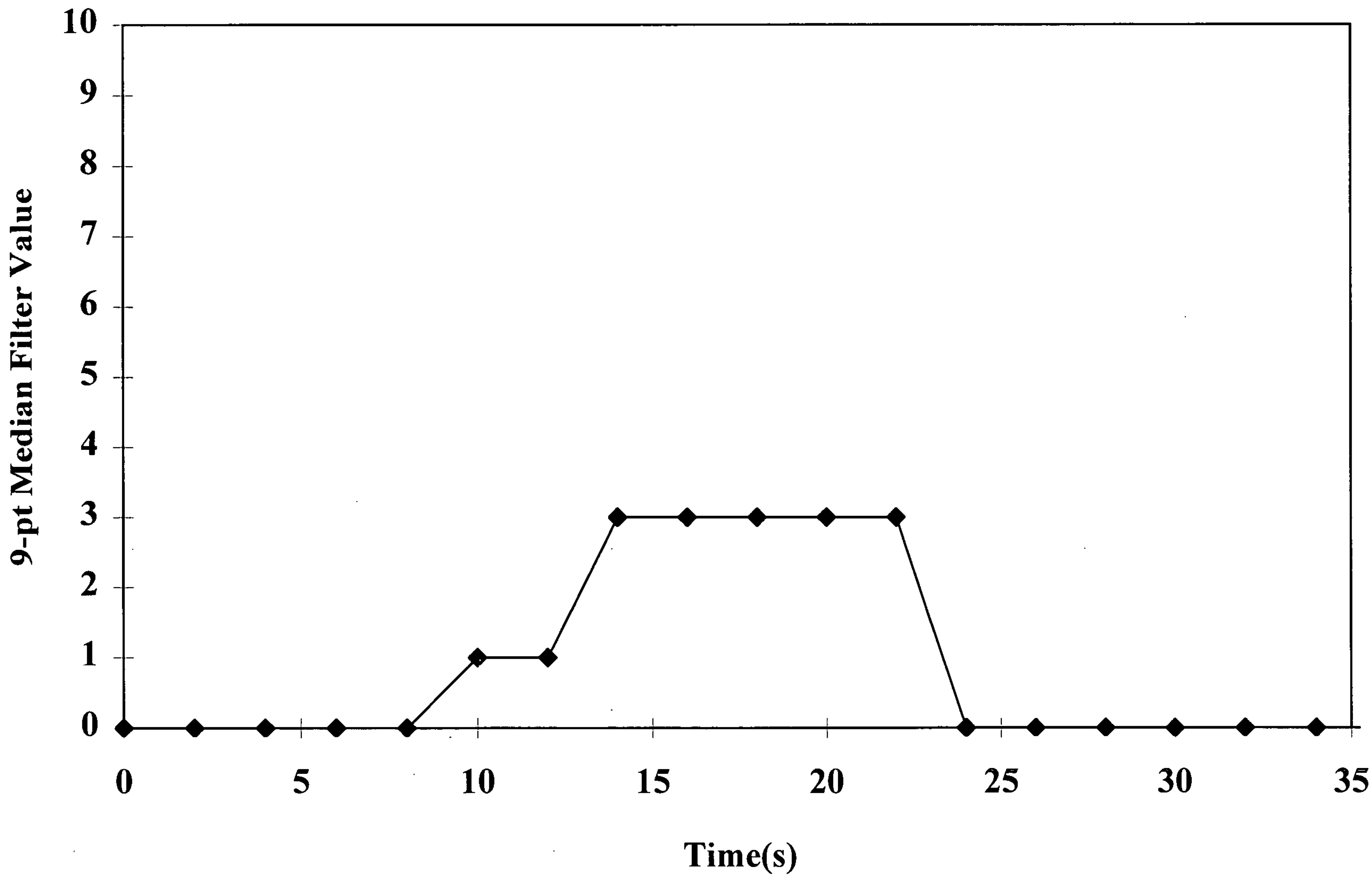
Example of a burst pellet event filtered with a 5-point median filter (sampling rate = 0.5 frames per second).



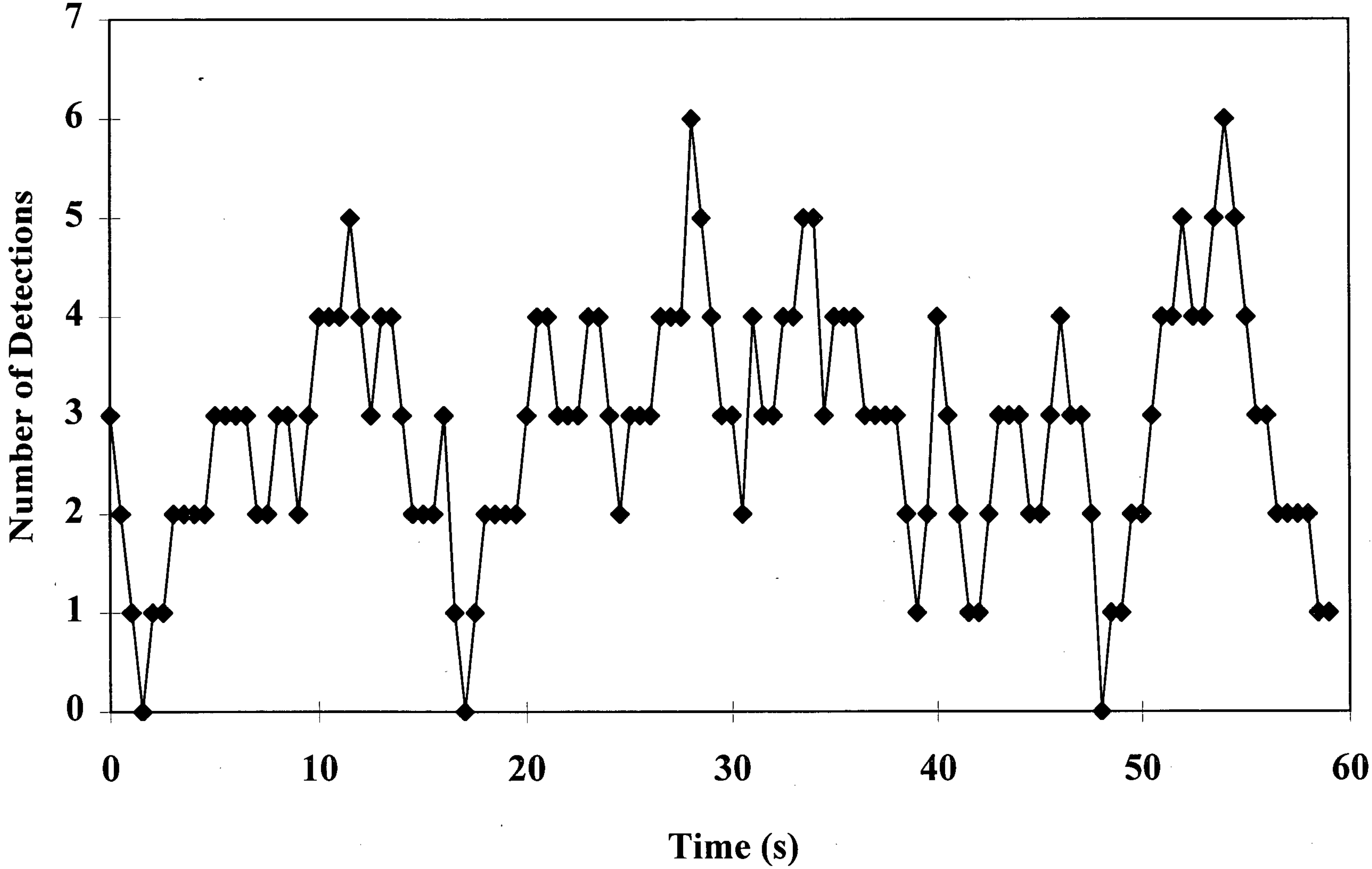
Example of a burst pellet event filtered with a 7-point median filter (sampling rate = 0.5 frames per second).



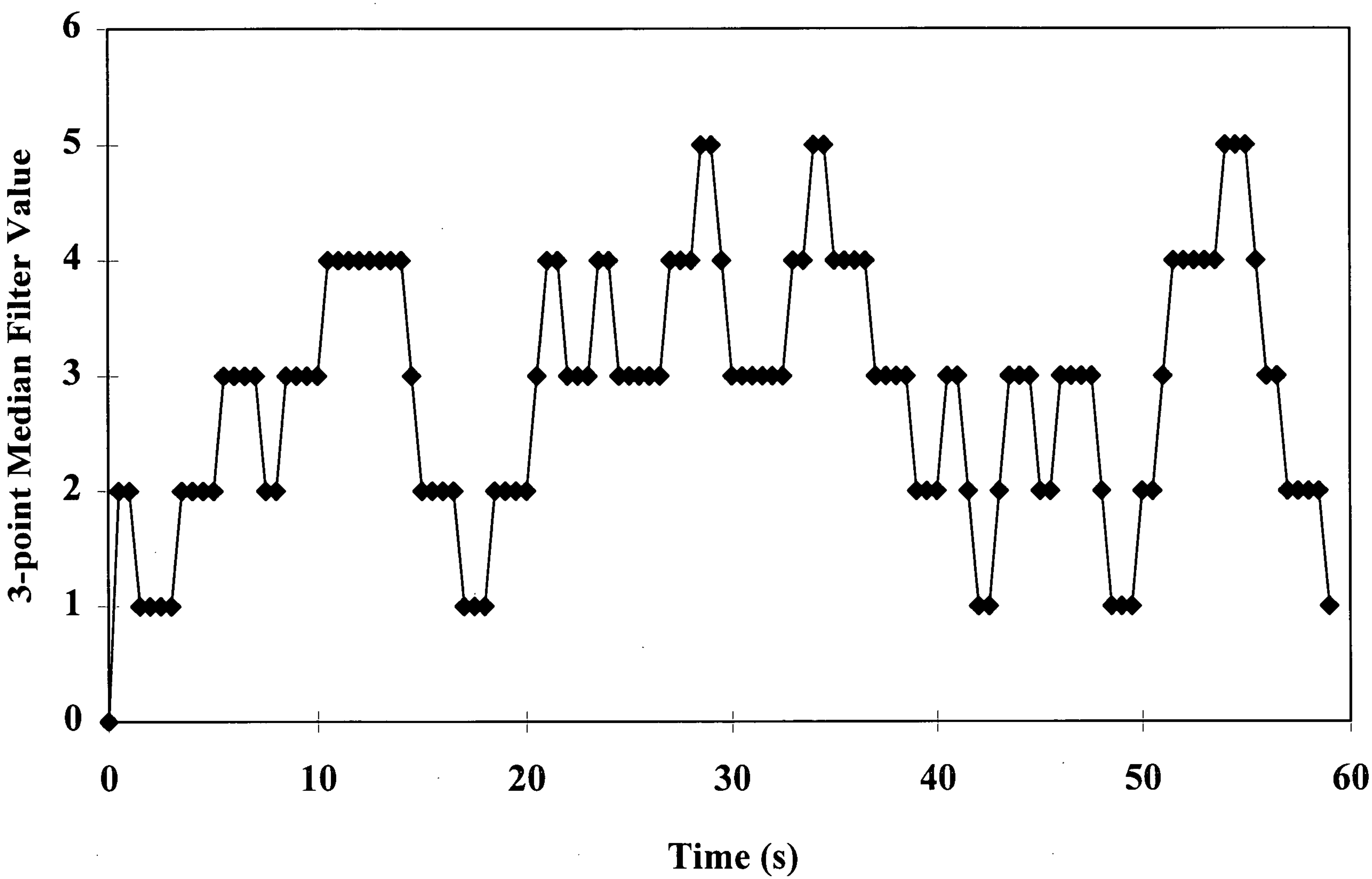
Example of a burst pellet event filtered with a 9-point median filter (sampling rate = 0.5 frames per second).



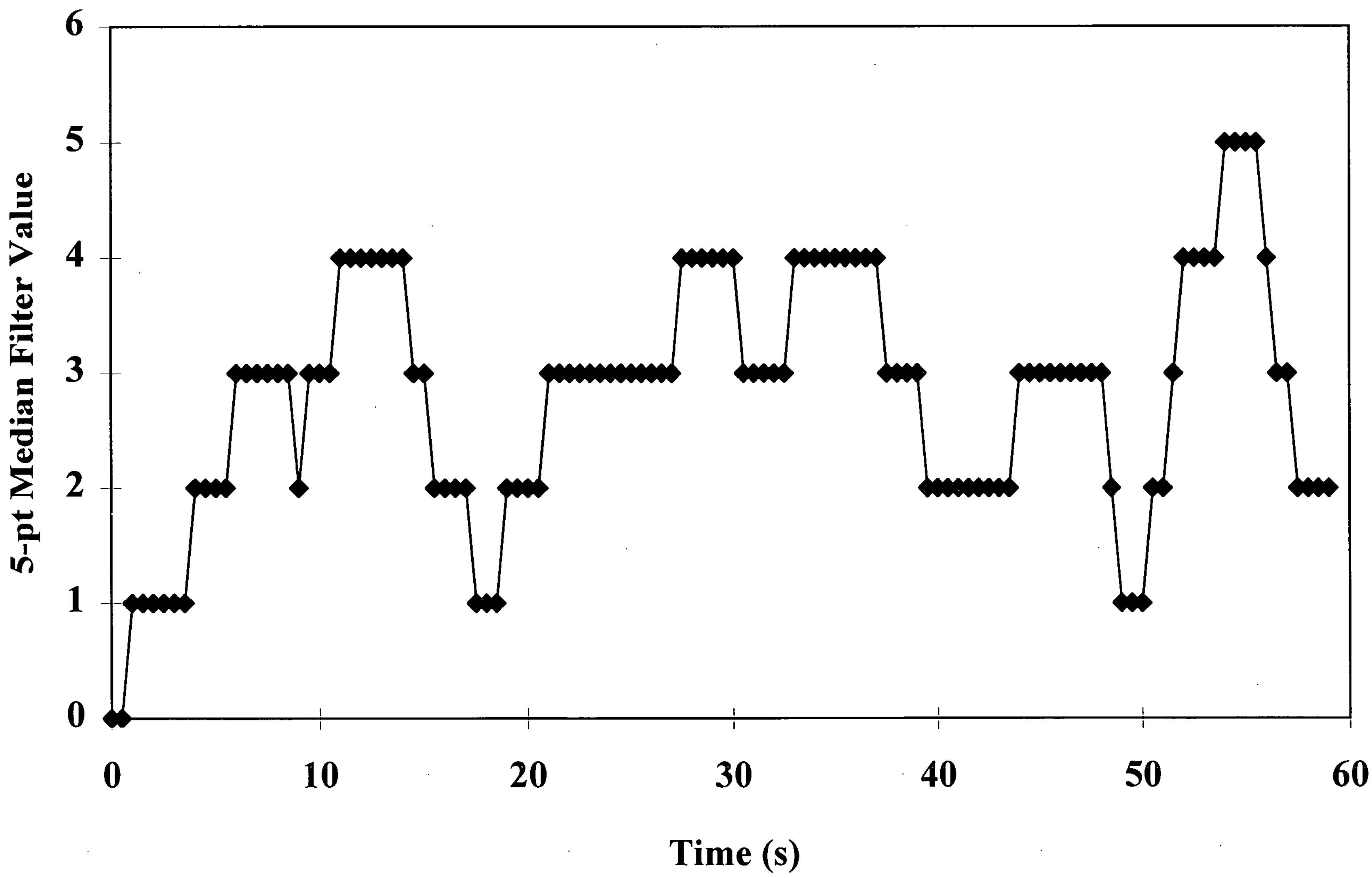
Example of a low intensity pellet event (sampling rate = 2 frames per second).



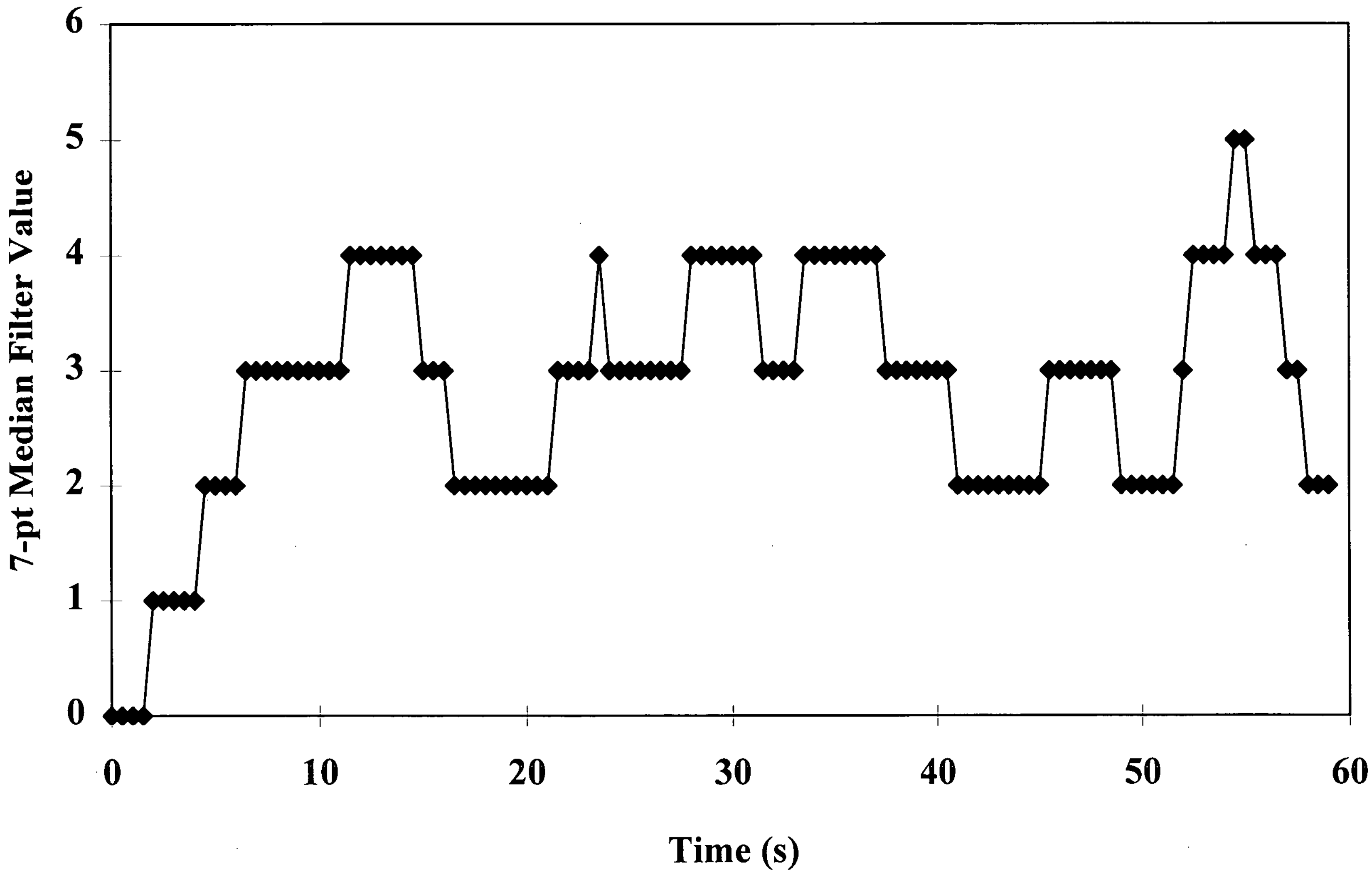
Example of a low intensity pellet event filtered with a 3-point median filter (sampling rate = 2 frames per second).



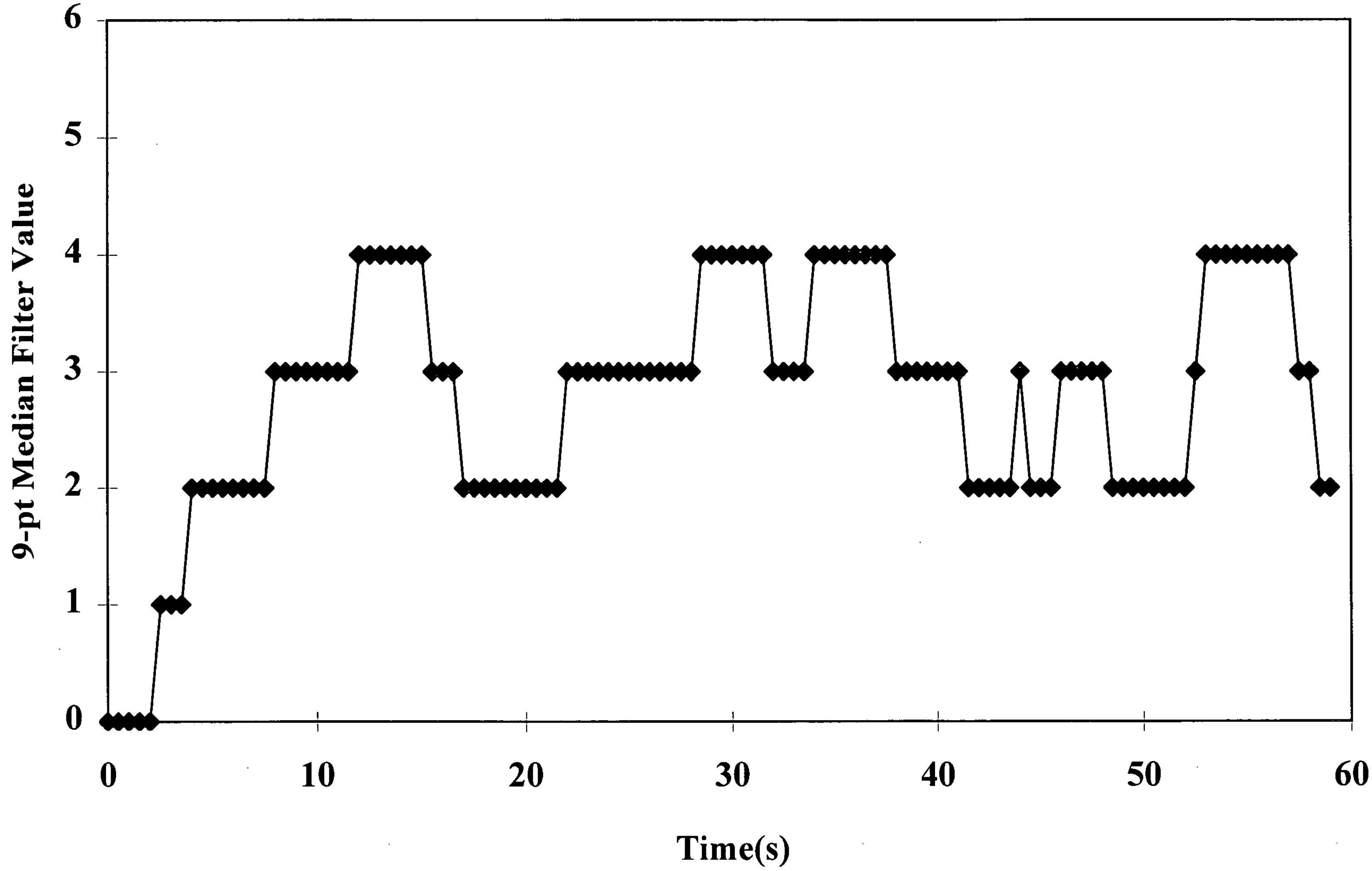
Example of a low intensity pellet event filtered with a 5-point median filter (sampling rate = 2 frames per second).



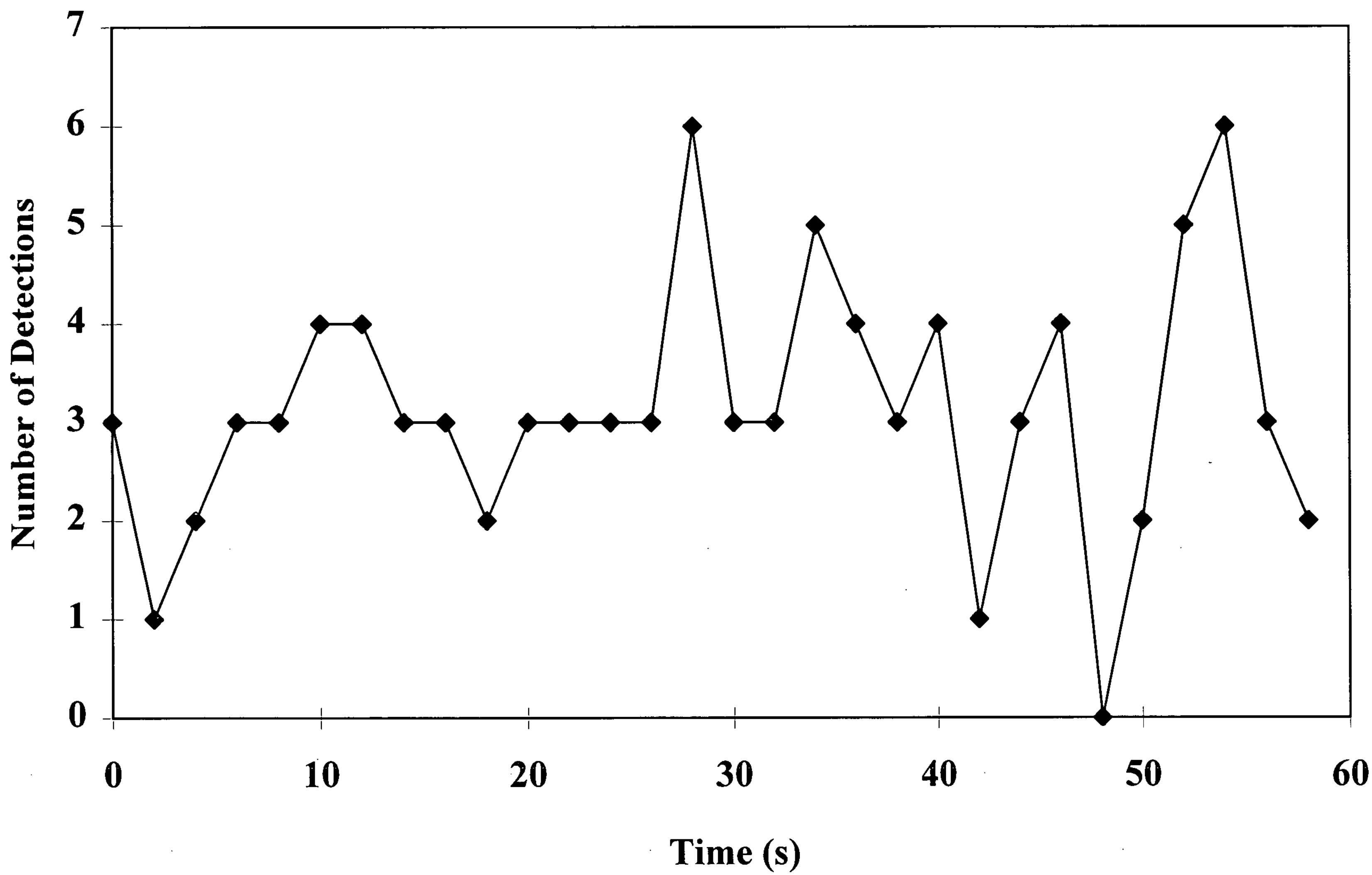
Example of a low intensity pellet event filtered with a 7-point median filter (sampling rate = 2 frames per second).



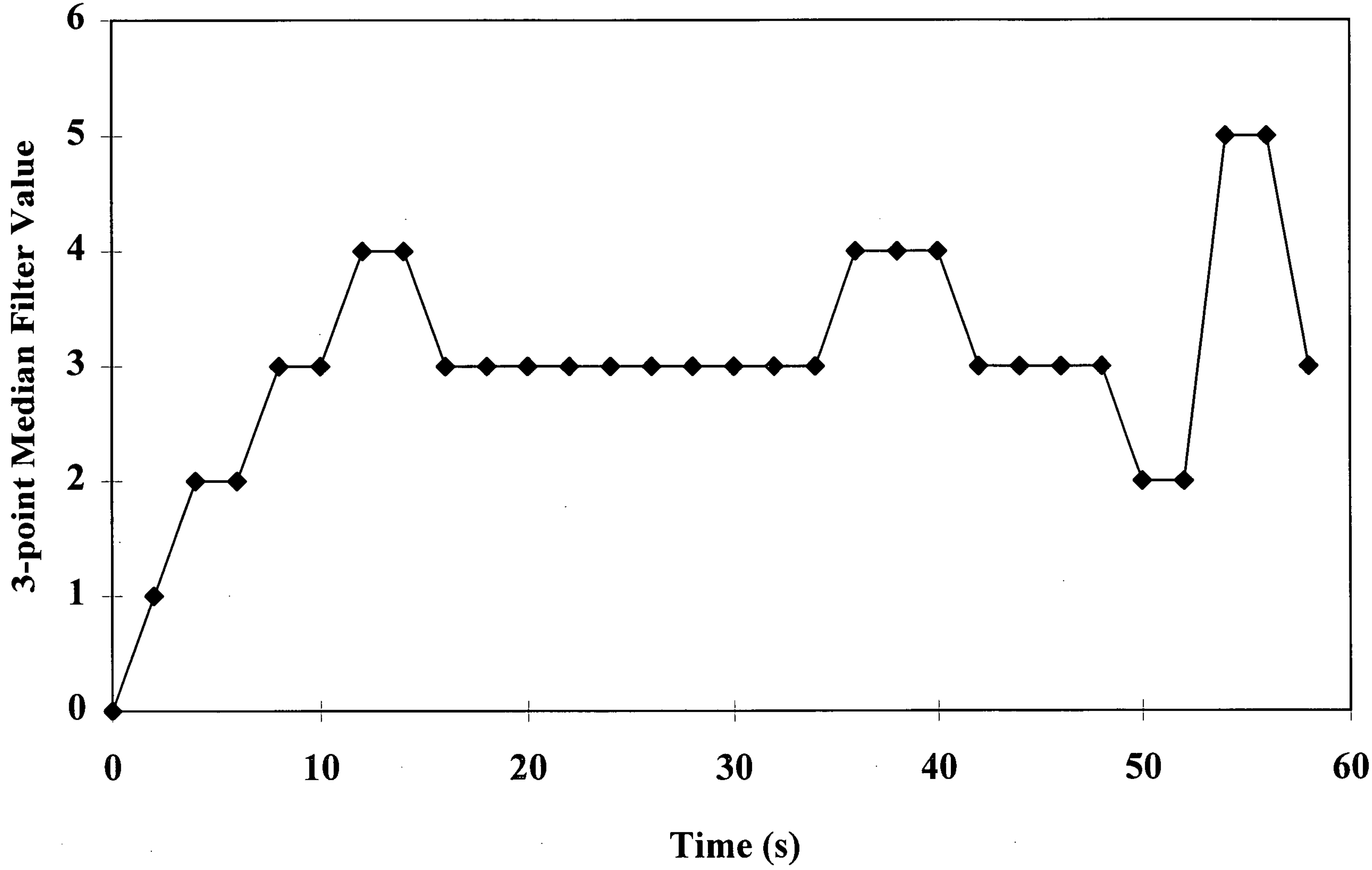
Example of a low intensity pellet event filtered with a 9-point median filter (sampling rate = 2 frames per second).



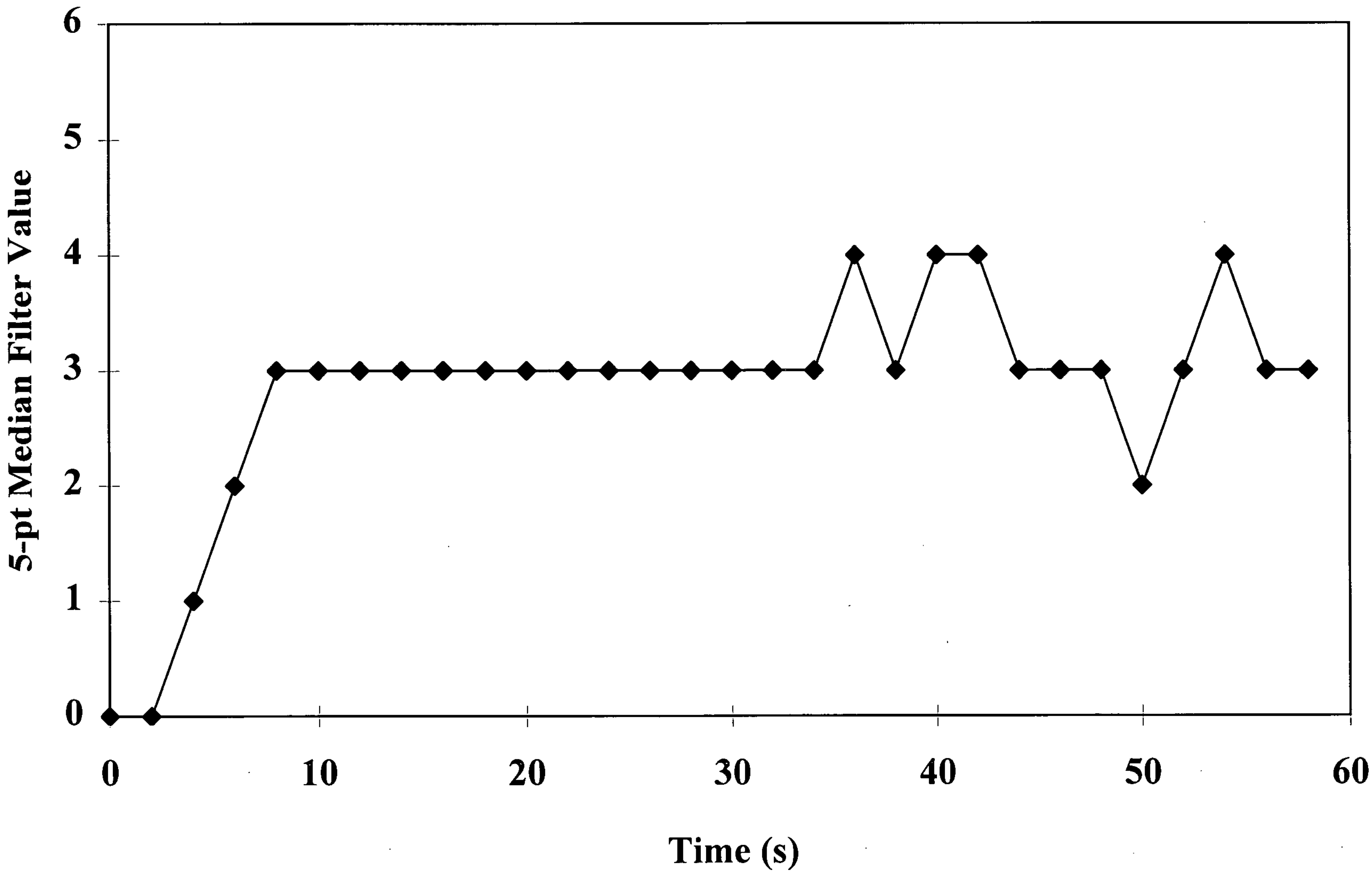
Example of a low intensity pellet event (sampling rate = 0.5 frames per second).



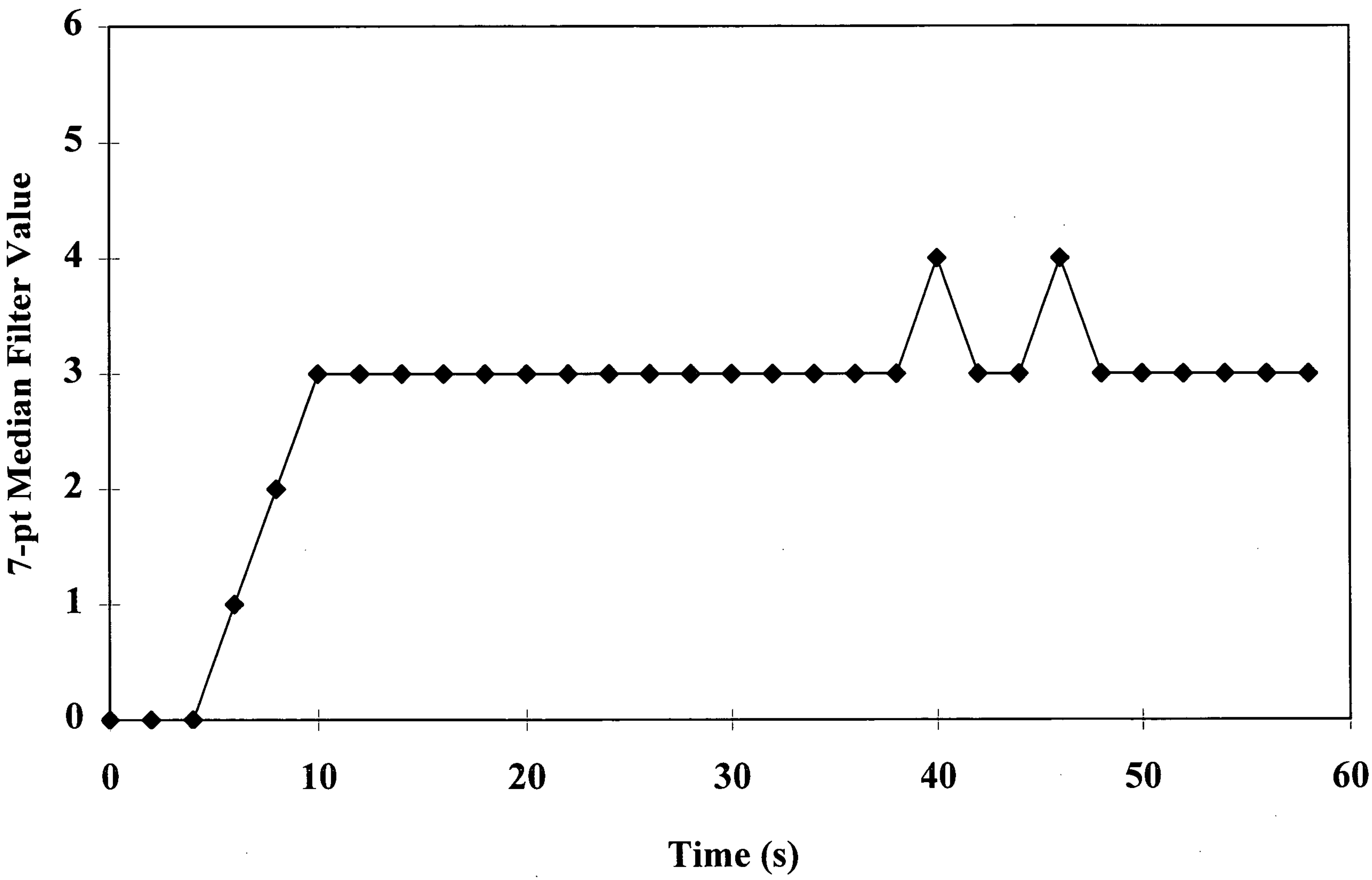
Example of a low intensity pellet event filtered with a 3-point median filter (sampling rate = 0.5 frames per second).



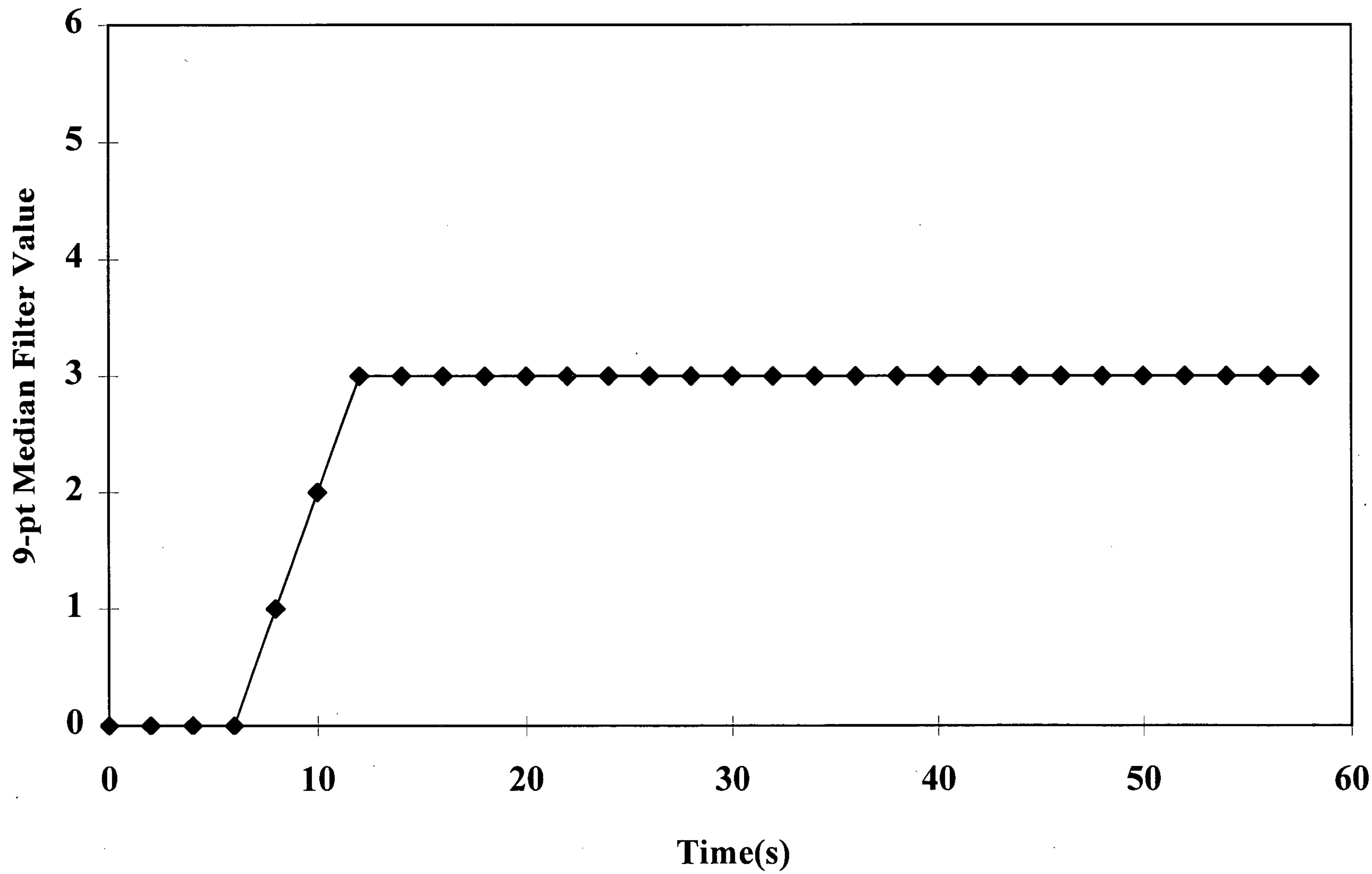
Example of a low intensity pellet event filtered with a 5-point median filter (sampling rate = 0.5 frames per second).



Example of a low intensity pellet event filtered with a 7-point median filter (sampling rate = 0.5 frames per second).



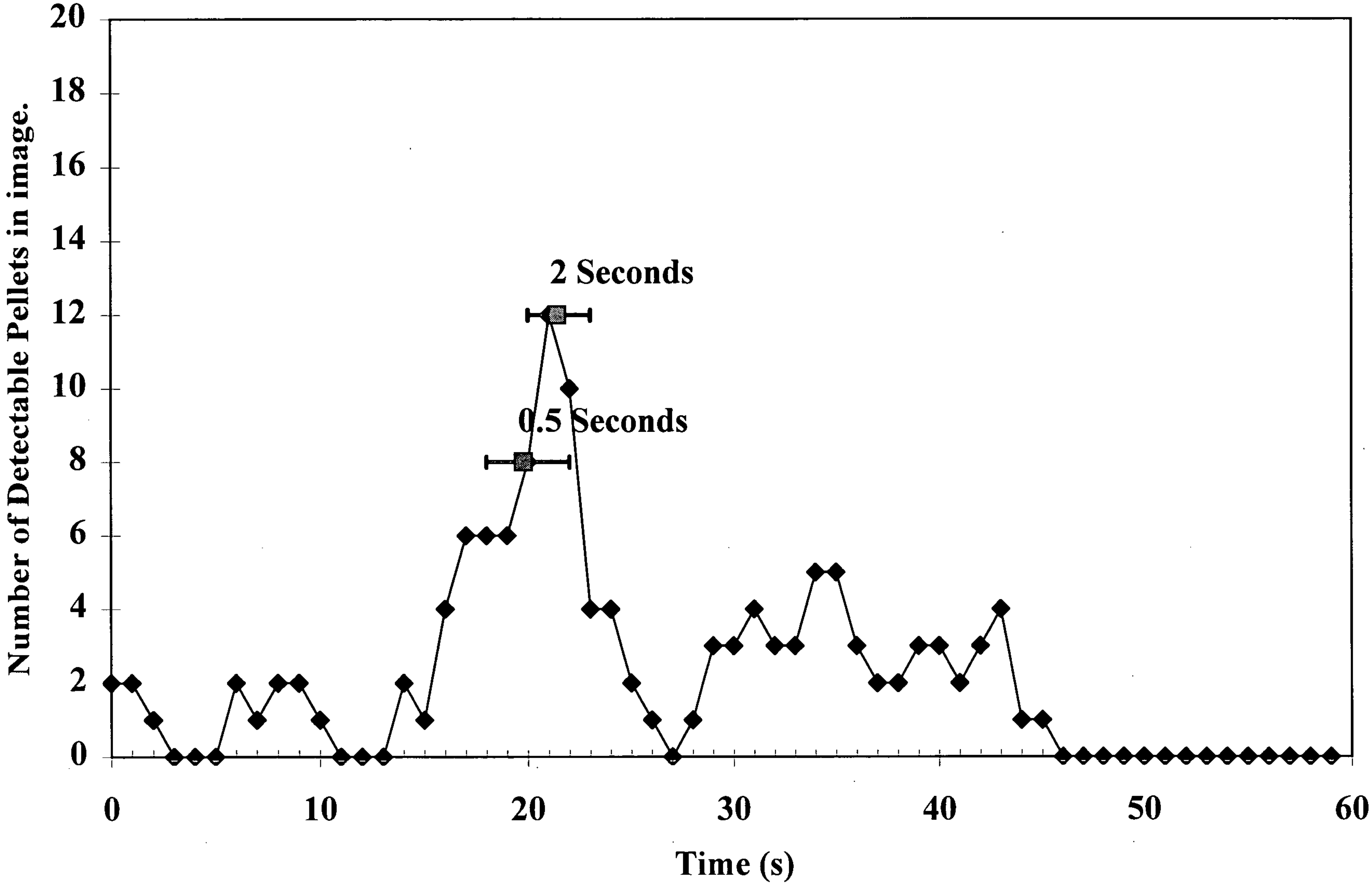
Example of a low intensity pellet event filtered with a 9-point median filter (sampling rate = 0.5 frames per second).



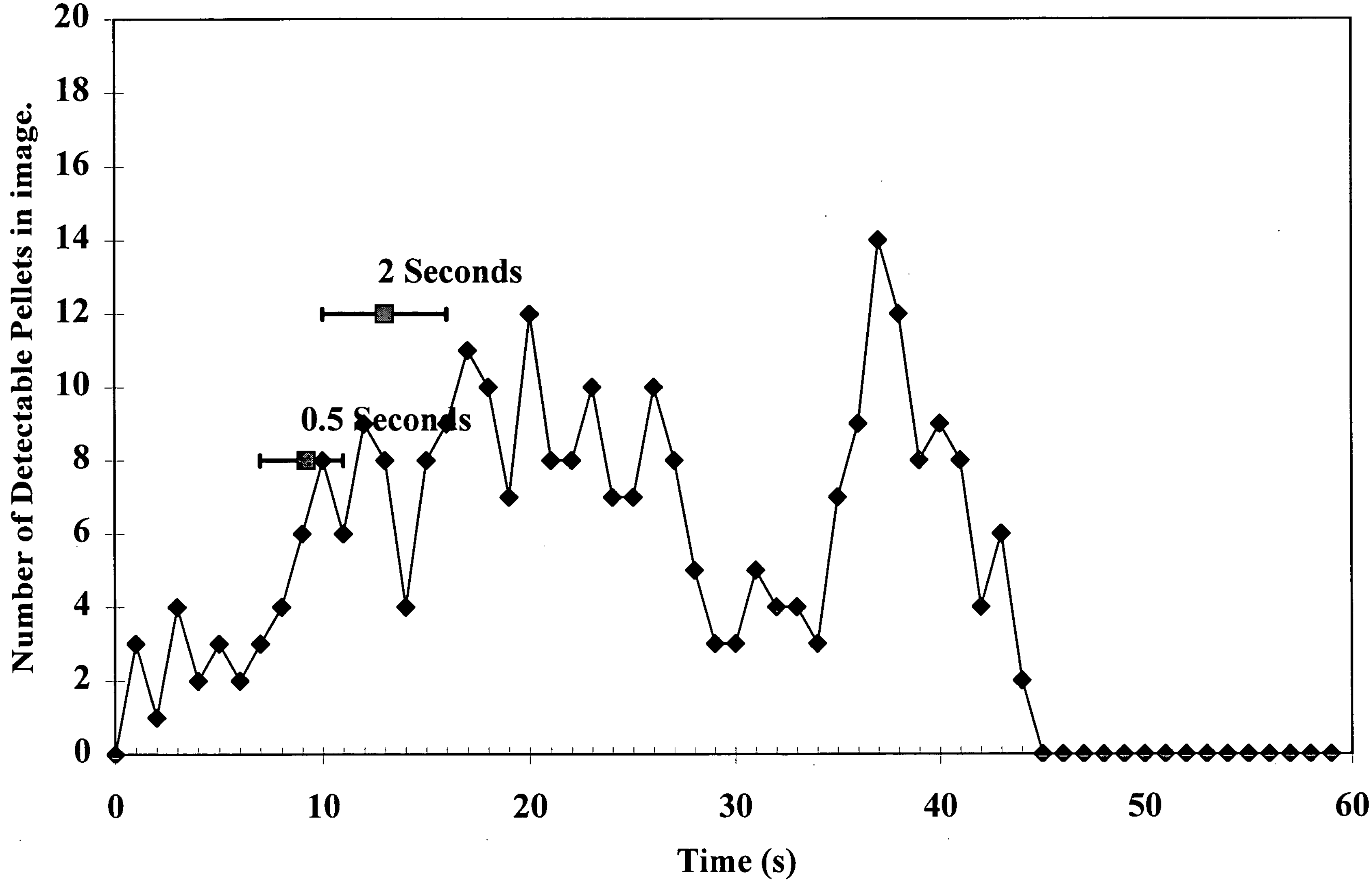
Appendix A.3

Dynamic Validation

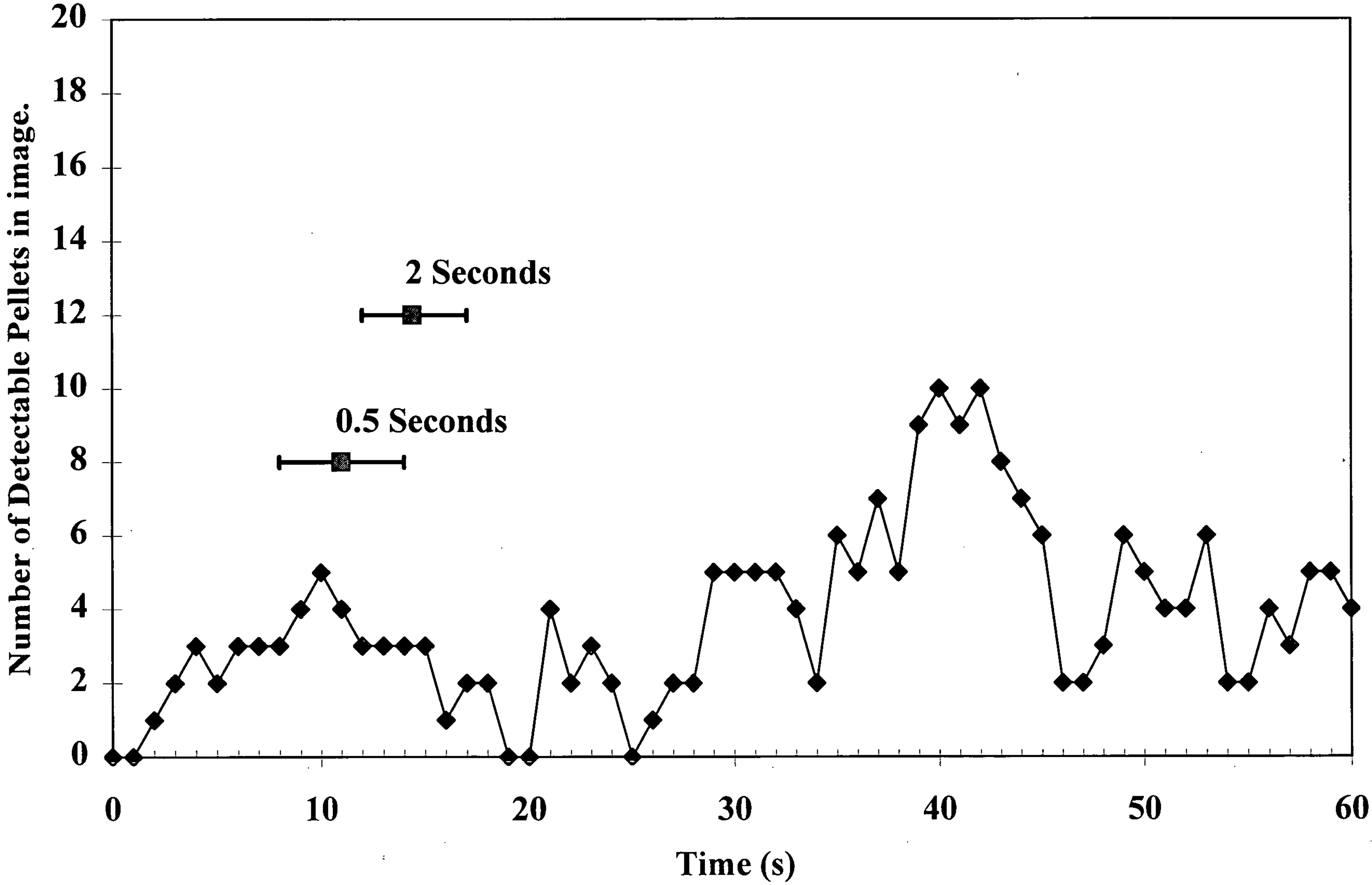
Sample: A, Date: July 12, 2001, Fish Size: 0.95 kg, Stocking Density: 2.5kg/m^3, Pellet Size: 6.5mm, Feeder Type: Pulse



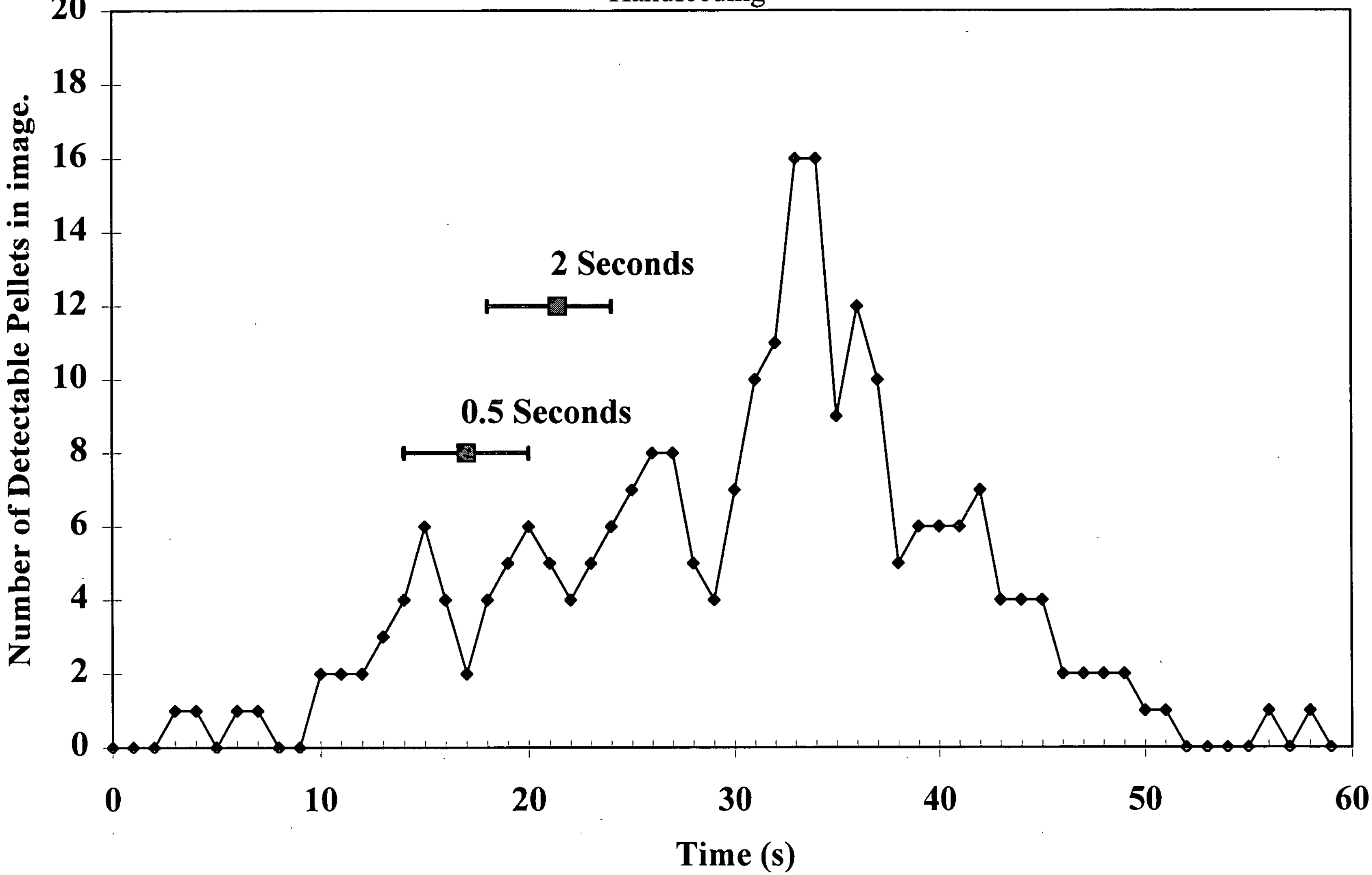
Sample: B, Date: July 12, 2001, Fish Size: 1.0 kg, Stocking Density: 2.4kg/m^3, Pellet Size: 6.5mm, Feeder Type: Pulse



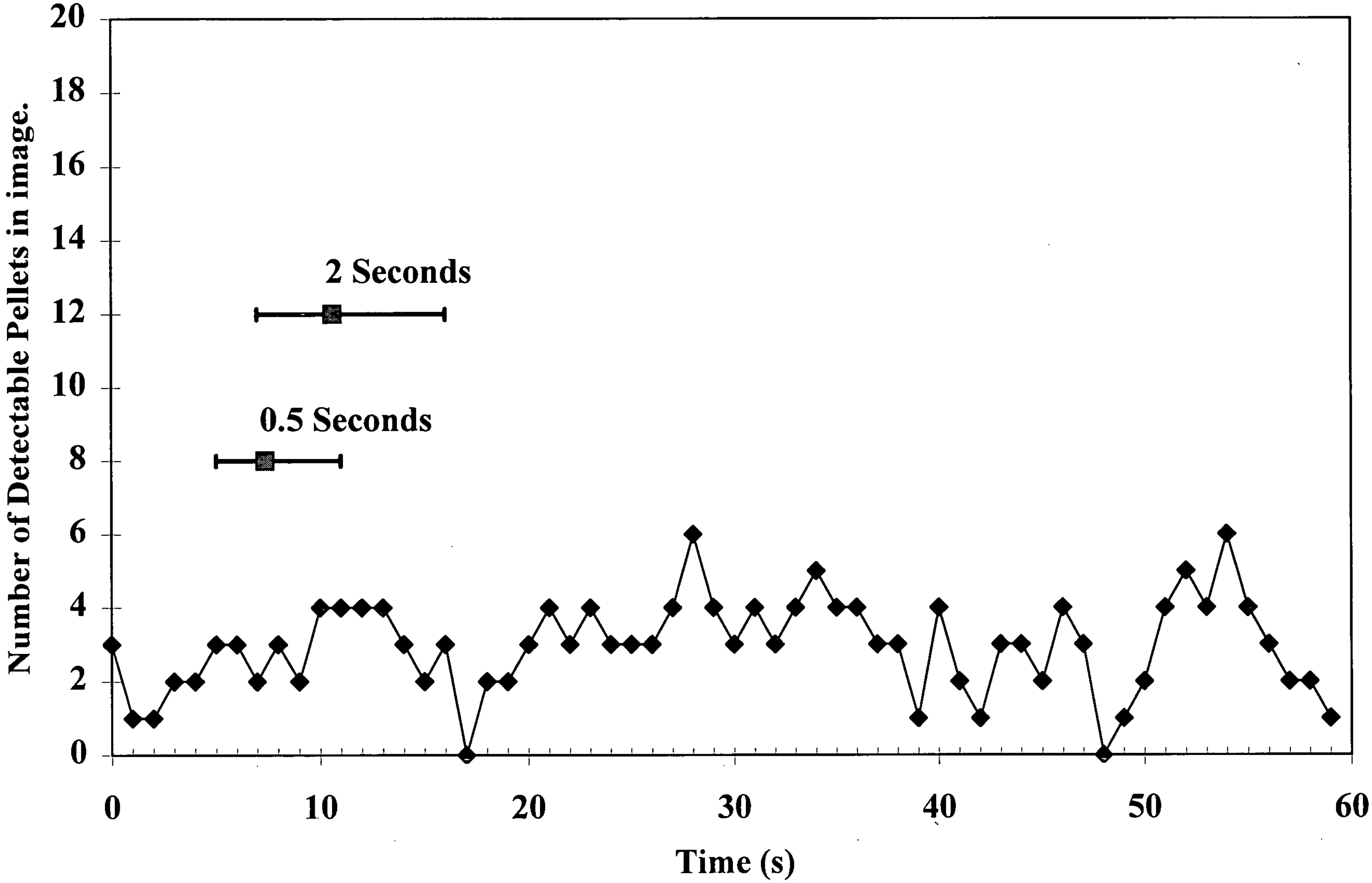
Sample: C, Date: July 12, 2001, Fish Size: 1.0kg, Stocking Density: $2.4 kg/m^3$, Pellet Size: 6.5mm, Feeder Type: Pulse



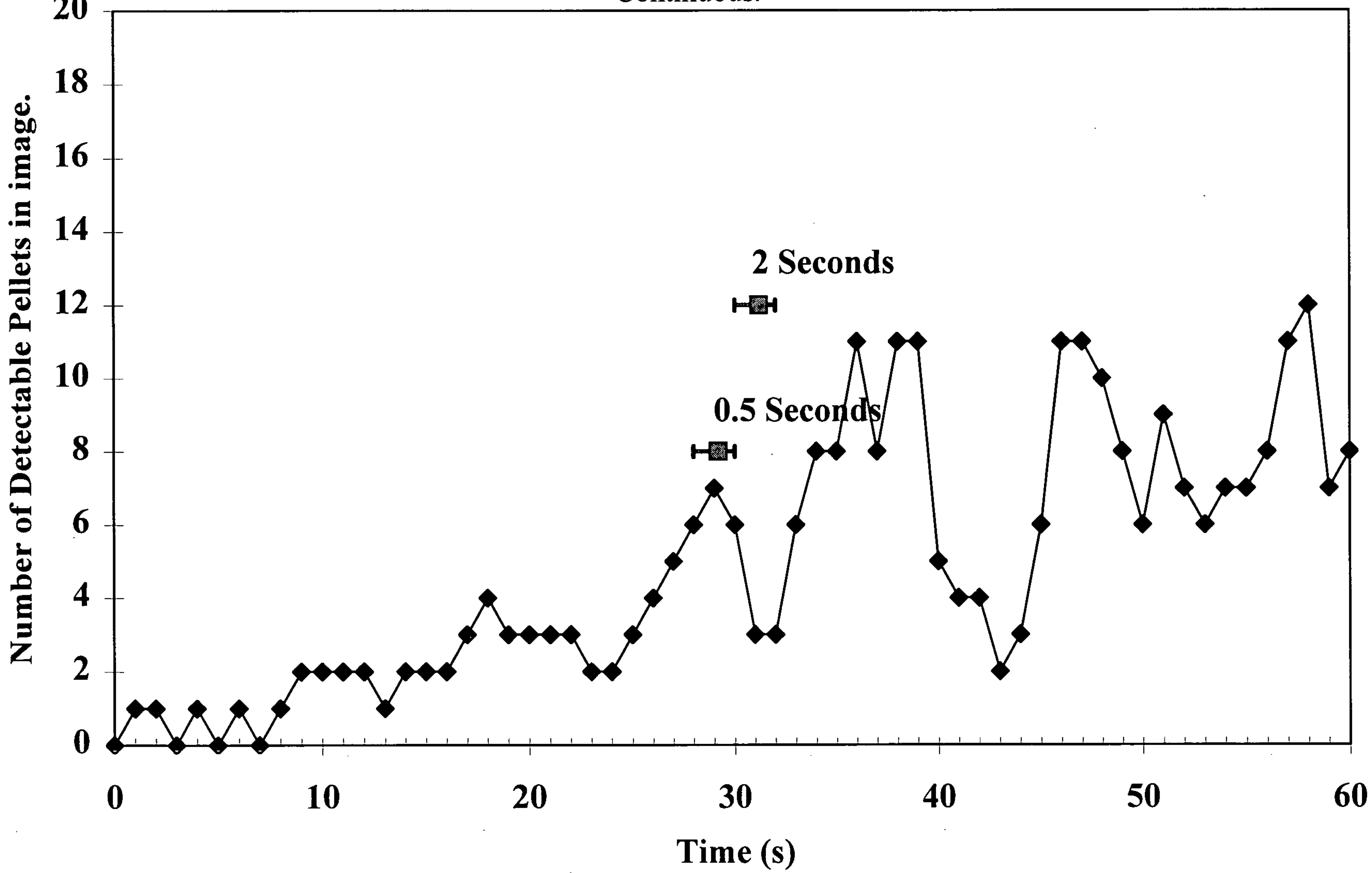
Sample: D, Date: July 12, 2001, Fish Size: 0.150 kg, Stocking Density: 0.3kg/m^3, Pellet Size: 3.5mm, Feeder Type: Handfeeding



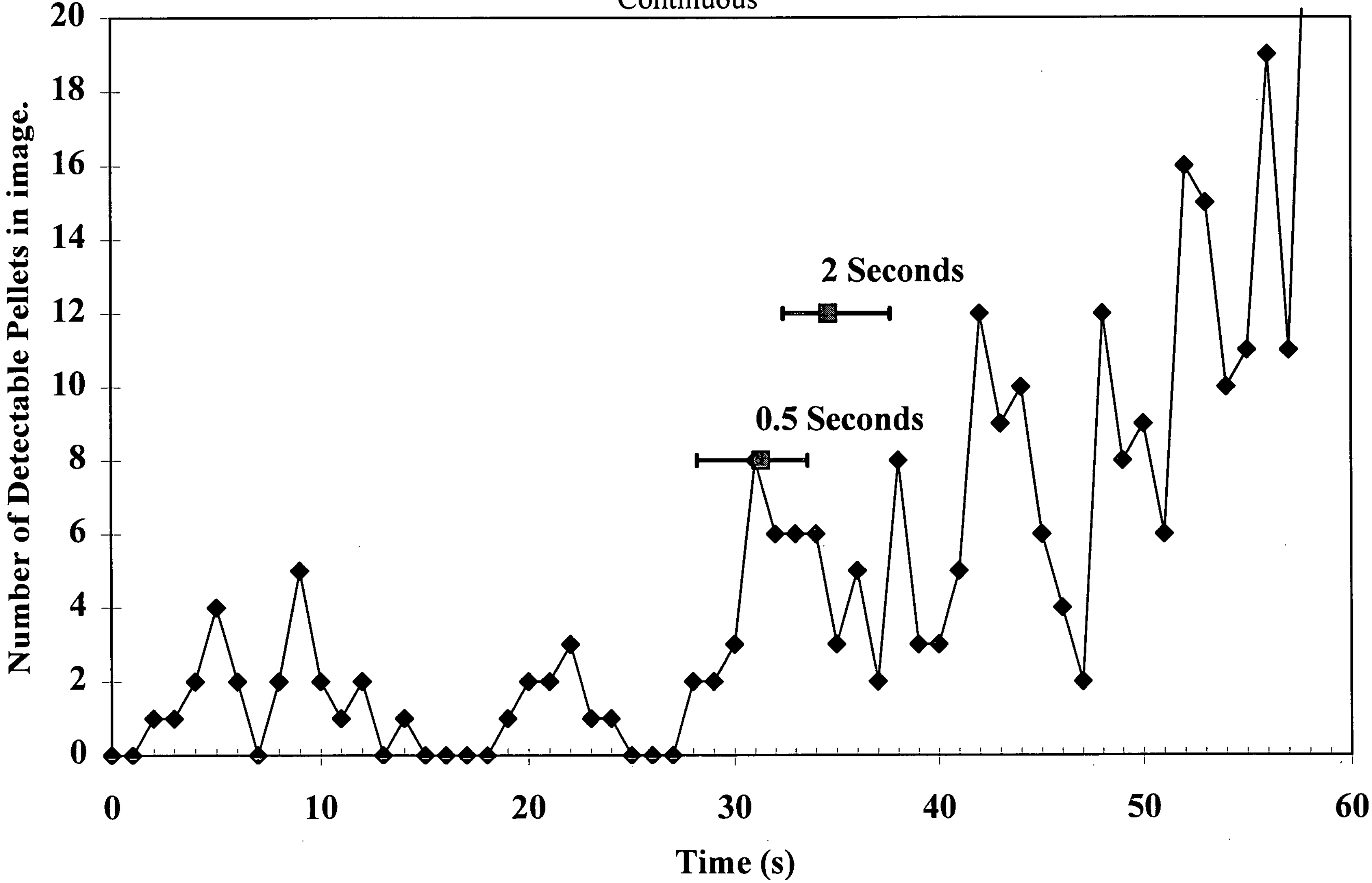
Sample: E Date: July 13, 2001, Fish Size: 0.025 kg, Stocking Density: 0.27kg/m^3, Pellet Size: 2.0mm, Feeder Type: Pulse



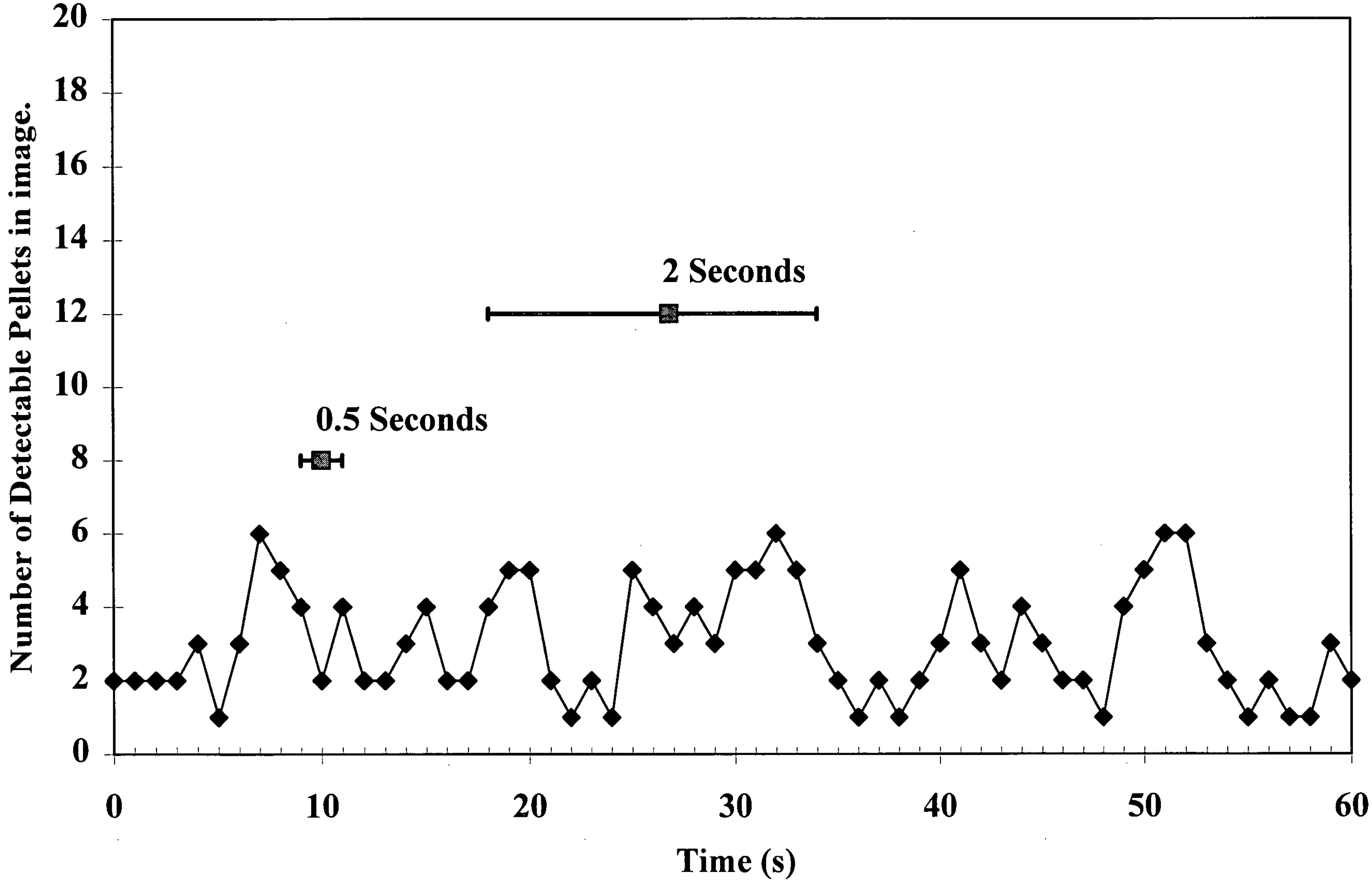
Sample: F, Date: October 10, 1994, Fish Size: 2.1kg , Stocking Density: 6.8kg/m^3, Pellet Size: 9mm, Feeder Type: Continuous.



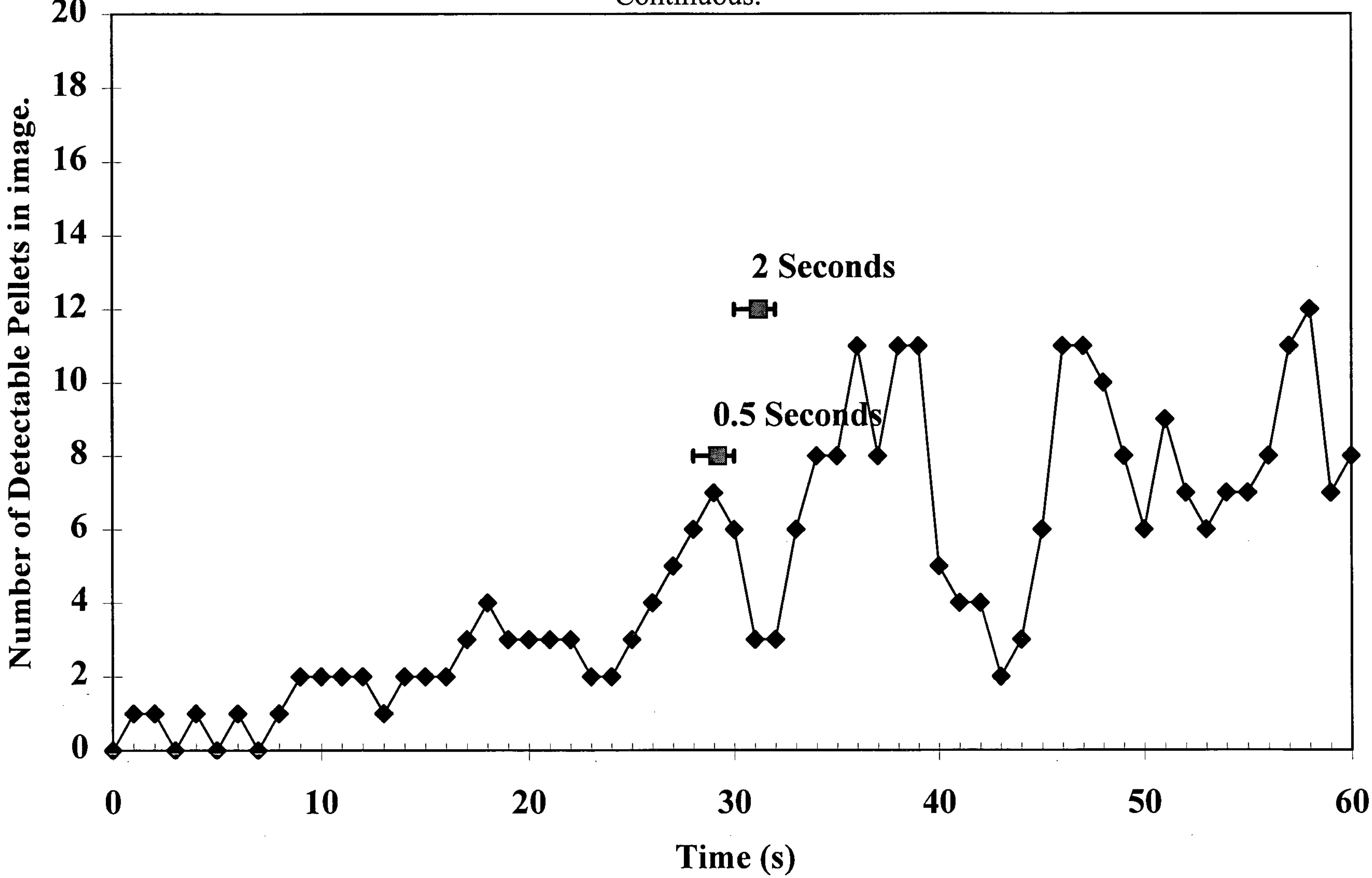
Sample: G, Date: August 5, 1997, Fish Size: 2.3kg, Stocking Density: 6.8kg/m^3, Pellet Size: 6.5-8.5mm, Feeder Type: Continuous



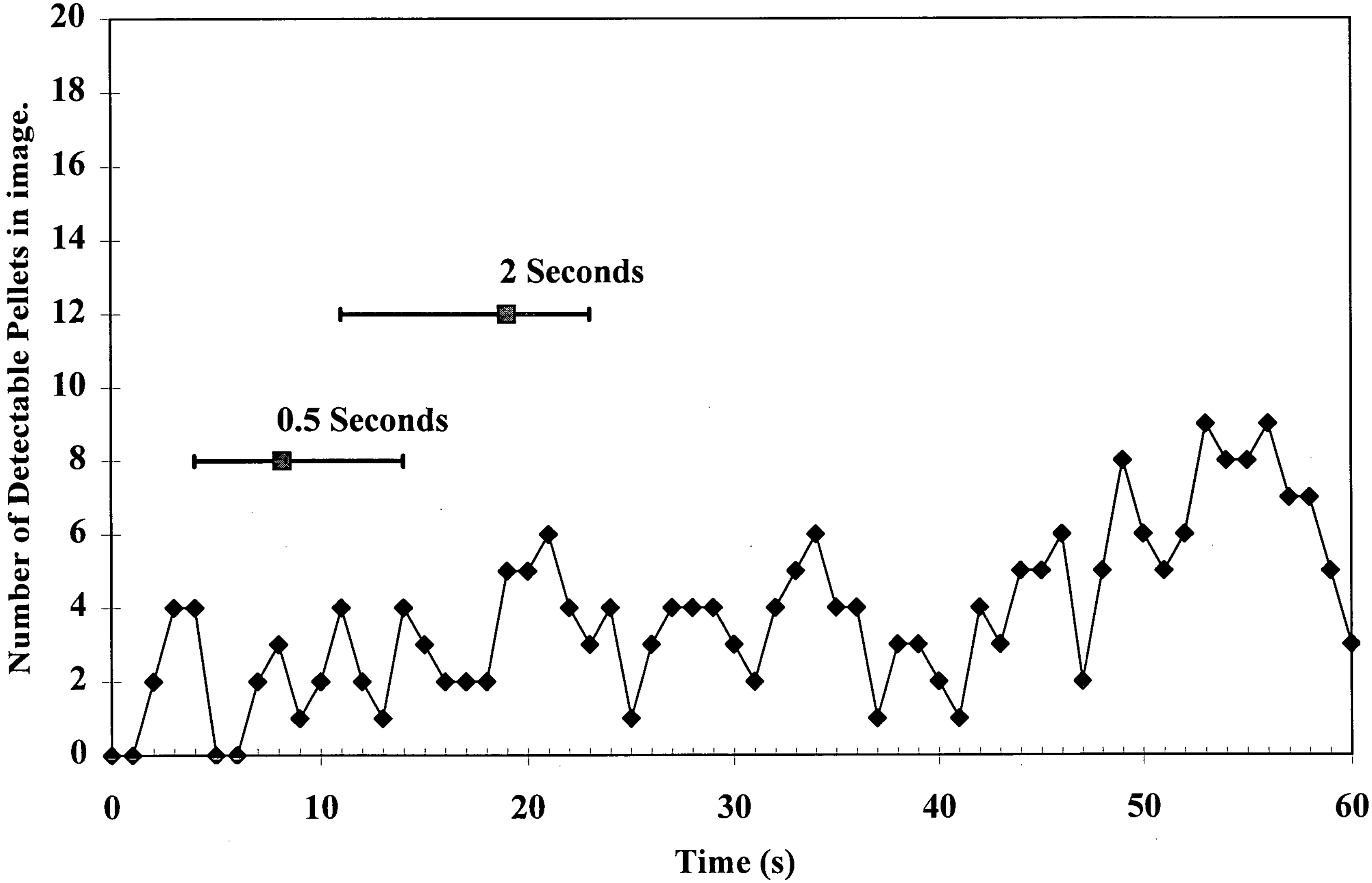
Sample: H, Date: July 11, 2001, Fish Size: 2.8kg, Stocking Density: 5.8kg/m^3, Pellet Size: 8.5mm, Feeder Type: Pulse



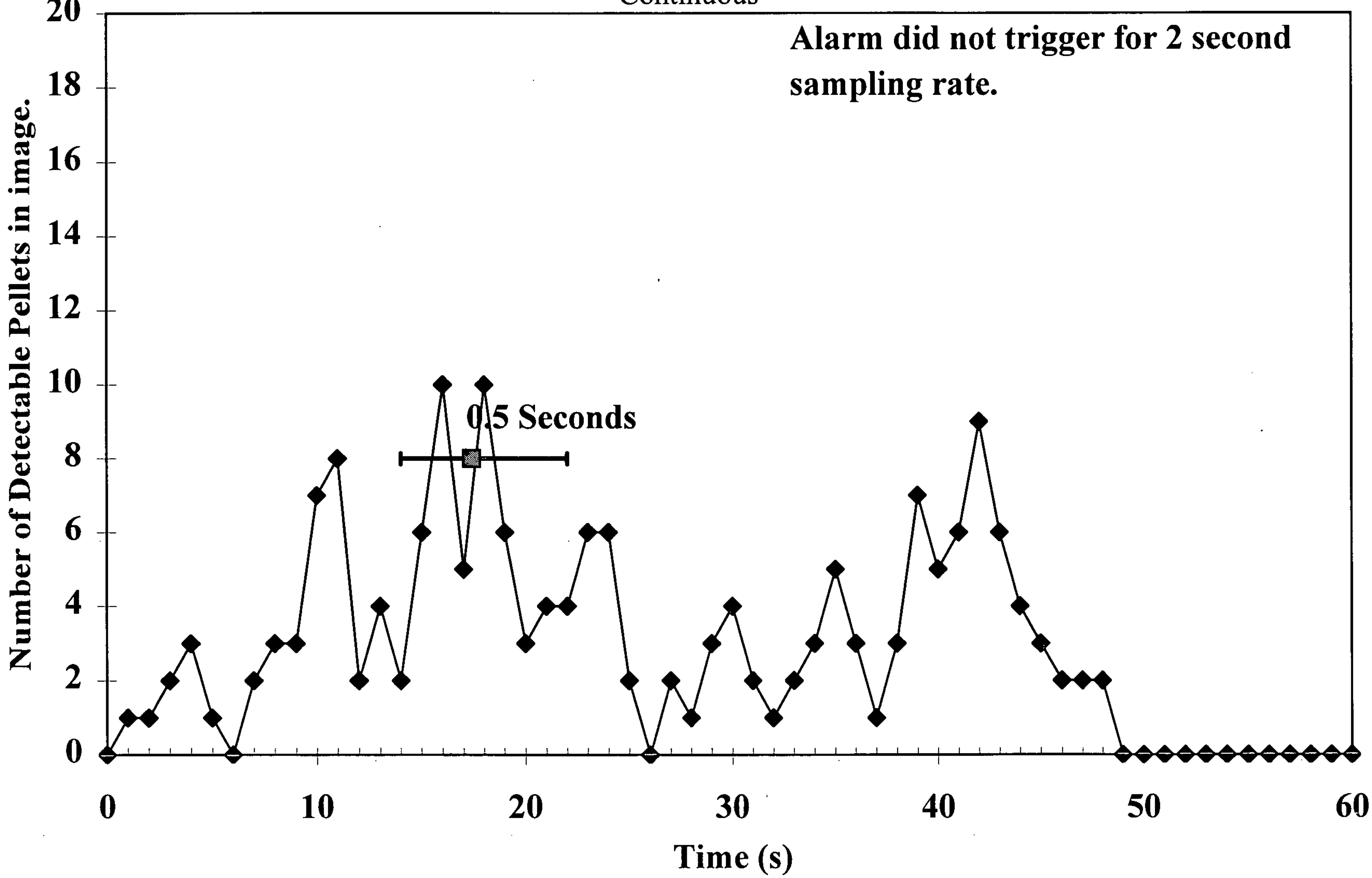
Sample: I, Date: October 10, 1994, Fish Size: 2.1kg , Stocking Density: 6.8kg/m^3, Pellet Size: 9mm, Feeder Type: Continuous.



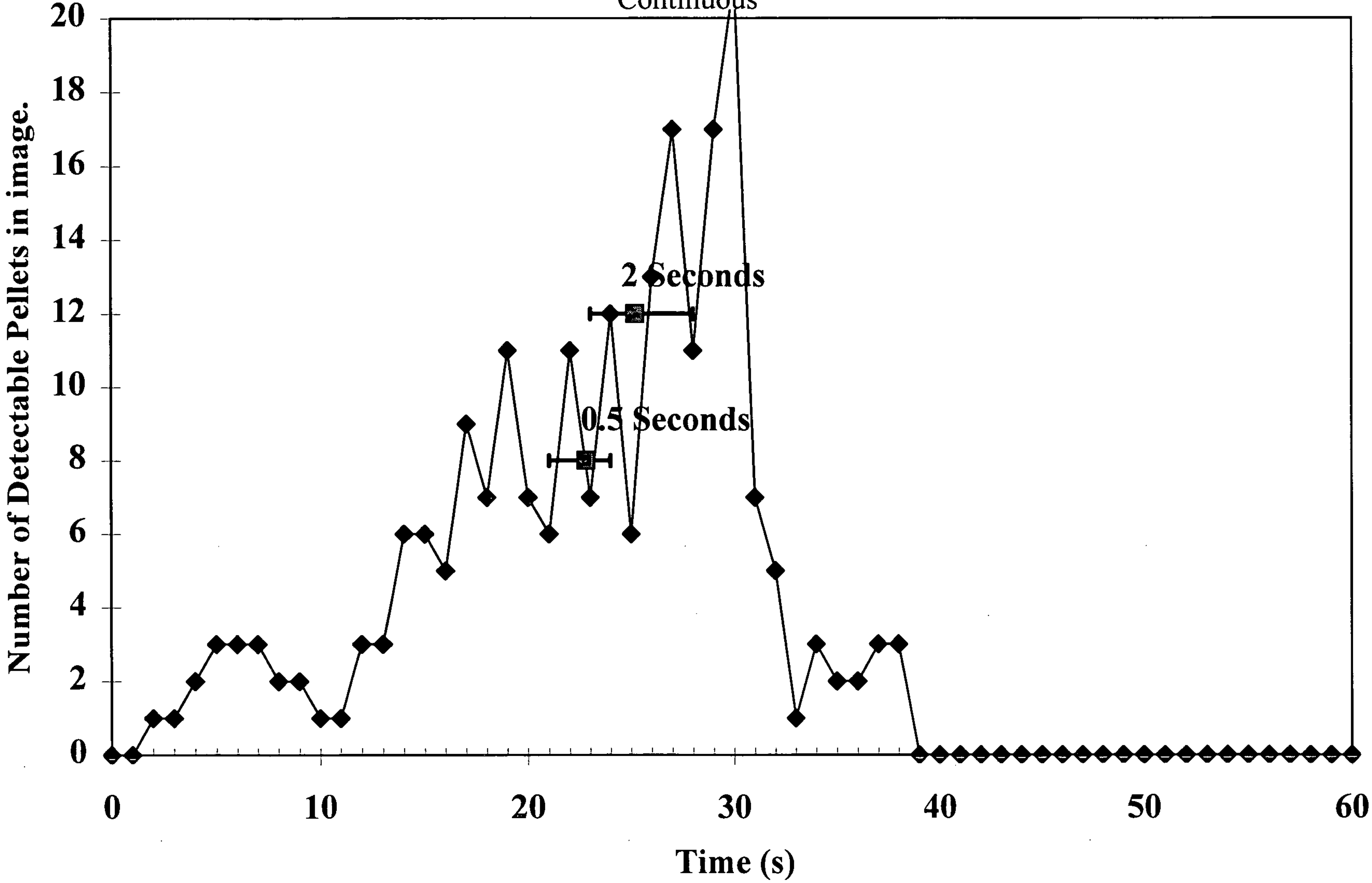
Sample: J, Date: July 11, 2001, Fish Size: 3.0kg, Stocking Density: 5.4kg/m^3, Pellet Size: 8.5mm, Feeder Type: Pulse



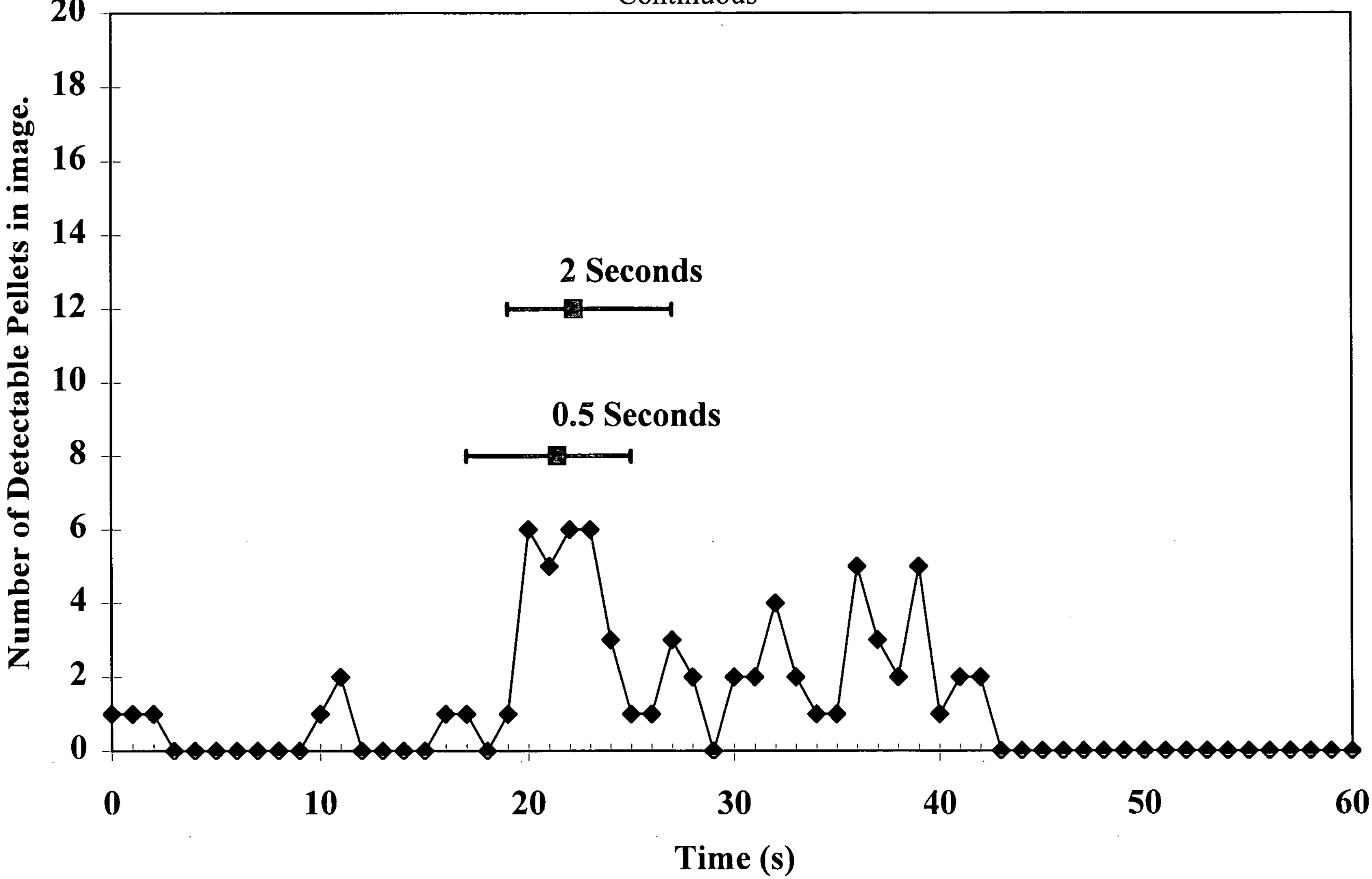
Sample: K, Date: August 6, 1997, Fish Size: 2.75kg, Stocking Density: 2.75kg/m^3, Pellet Size: 8.5mm, Feeder Type: Continuous



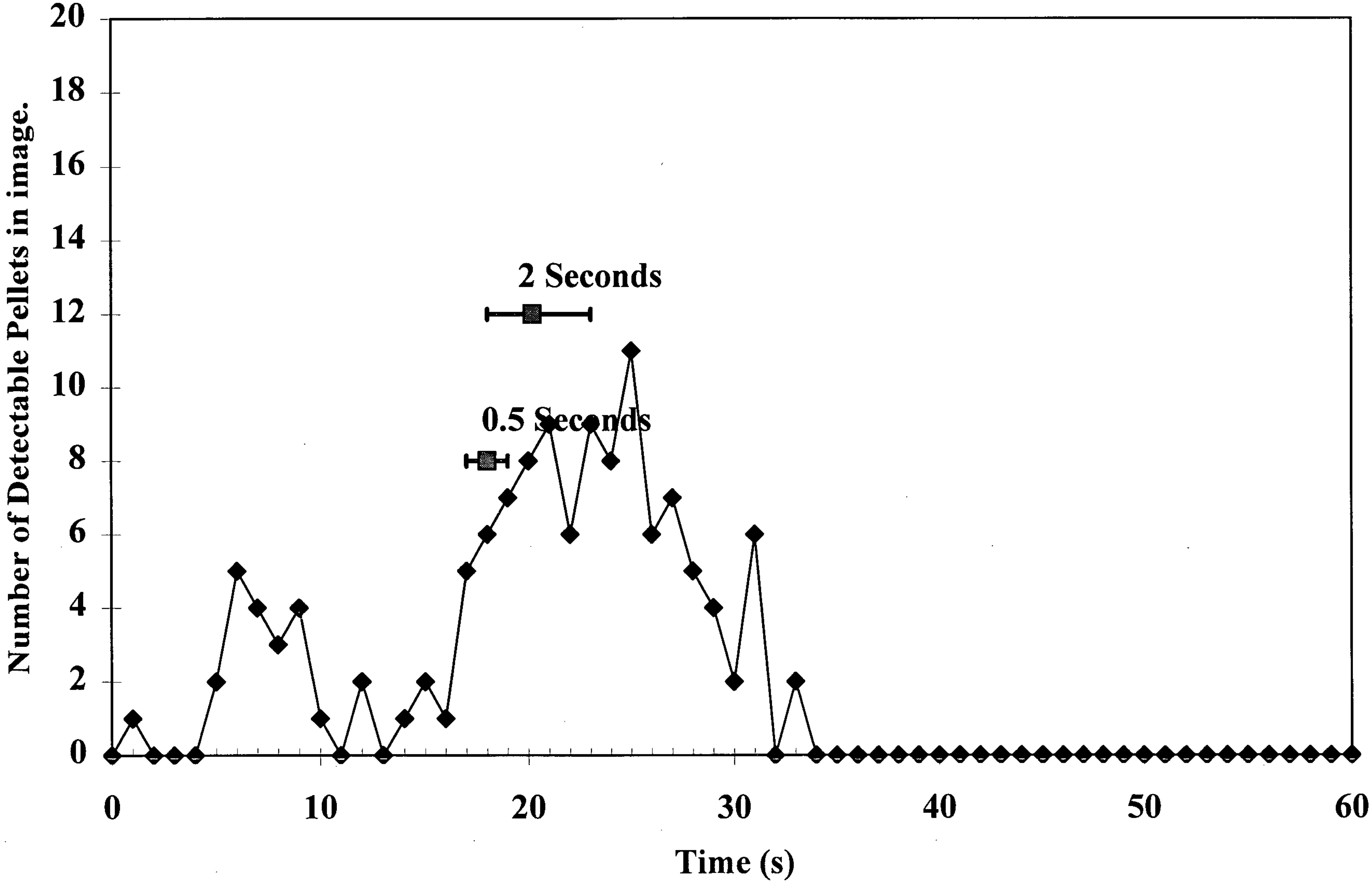
Sample: L, Date: August 8, 1997, Fish Size: 2.8kg, Stocking Density 11.0kg/m^3, Pellet Size: 8.5mm, Feeder Type: Continuous



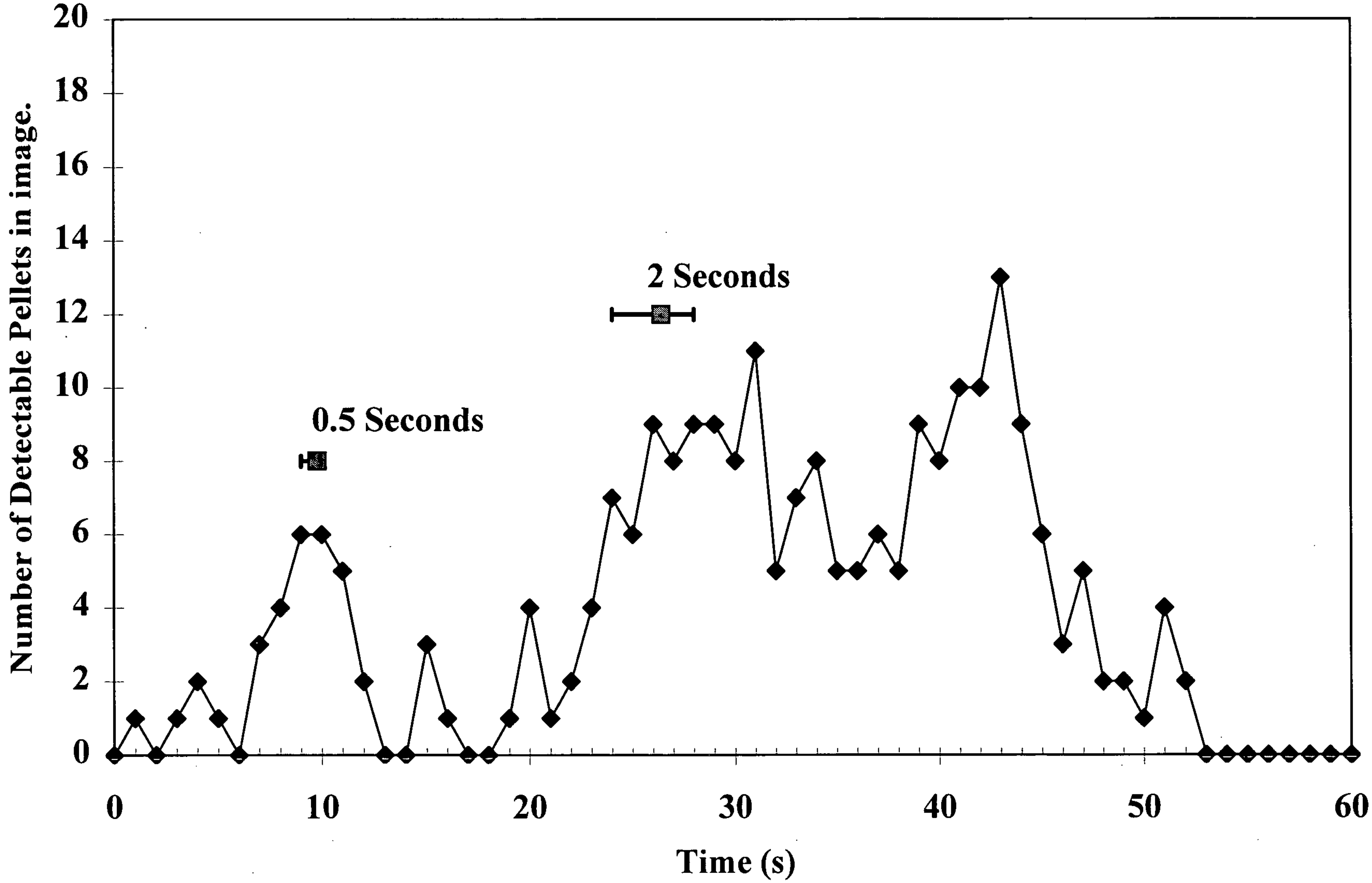
Sample: M, Date: August 9, 1997, Fish Size: 2.7kg, Stocking Density 10.4kg/m^3, Pellet Size: 8.5mm, Feeder Type: Continuous



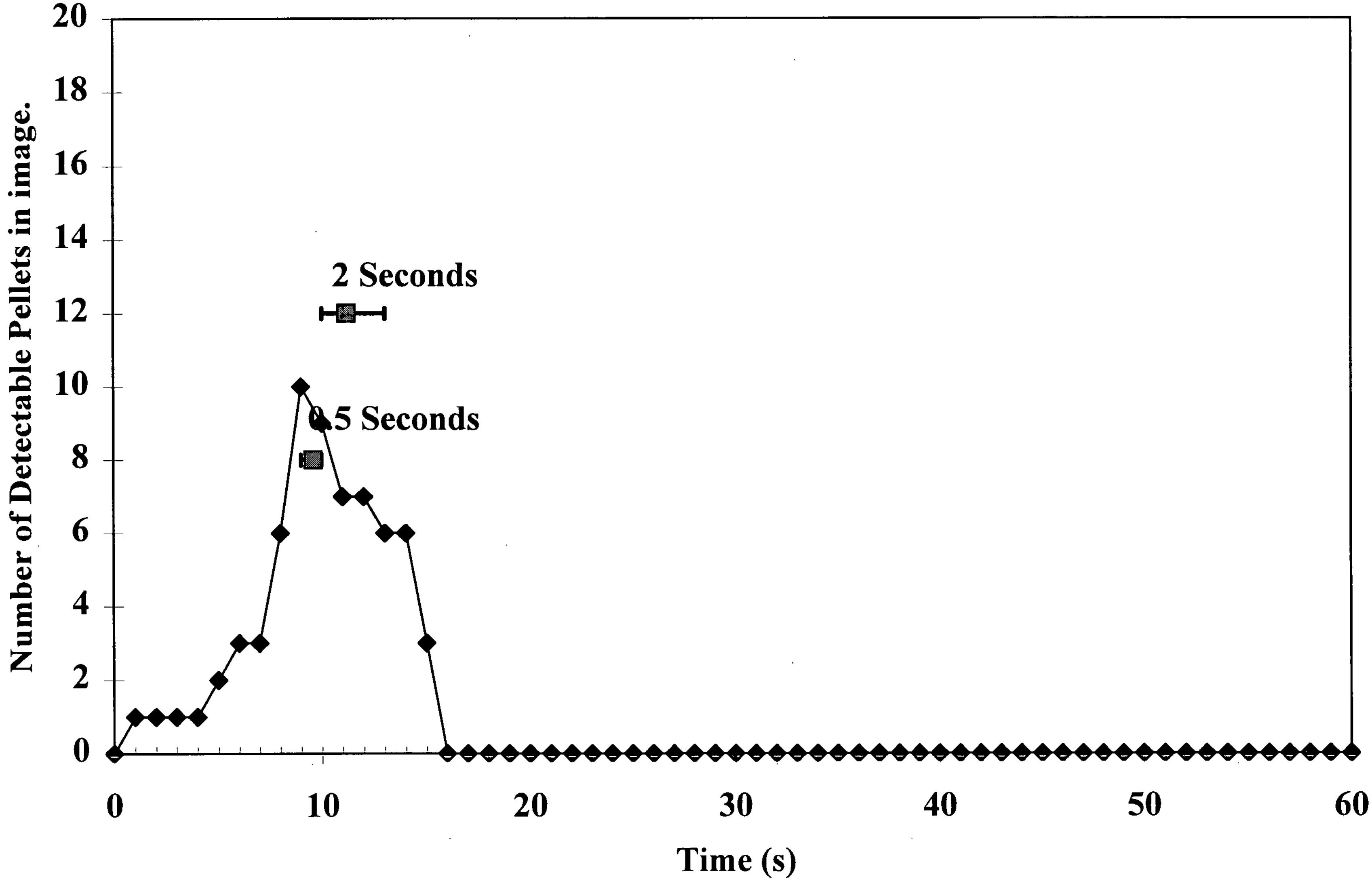
Sample: N, Date: June 27, 2000, Fish Size: 4.8kg, Stocking Density: $17kg/m^3$, Pellet Size: 9mm, Feeder Type: Pulse



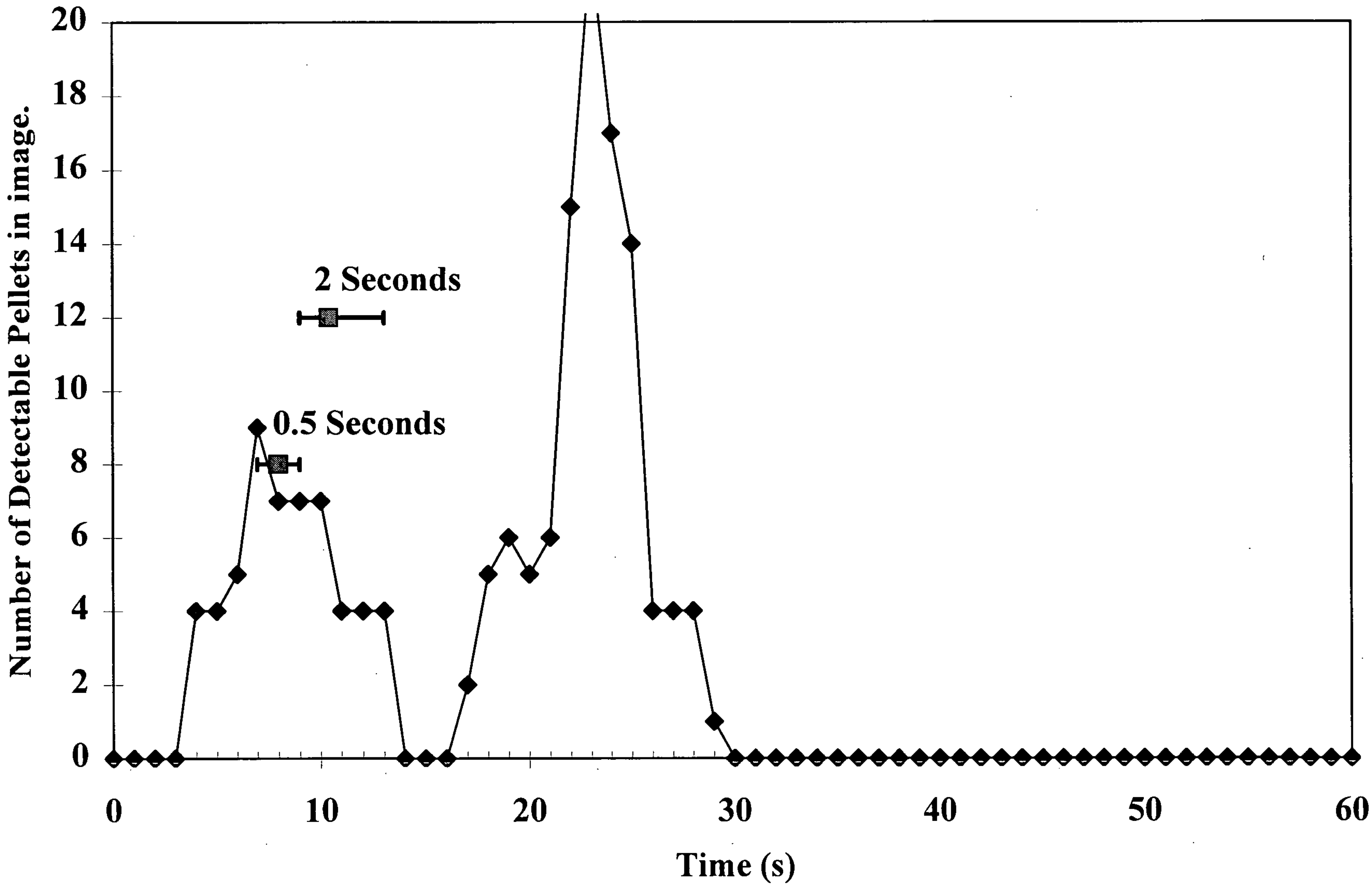
Sample: O, Date: June 27, 2000, Fish Size: 3.8kg, Stocking Density: 11.0kg/m^3, Pellet Size: 9mm, Feeder Type: Pulse



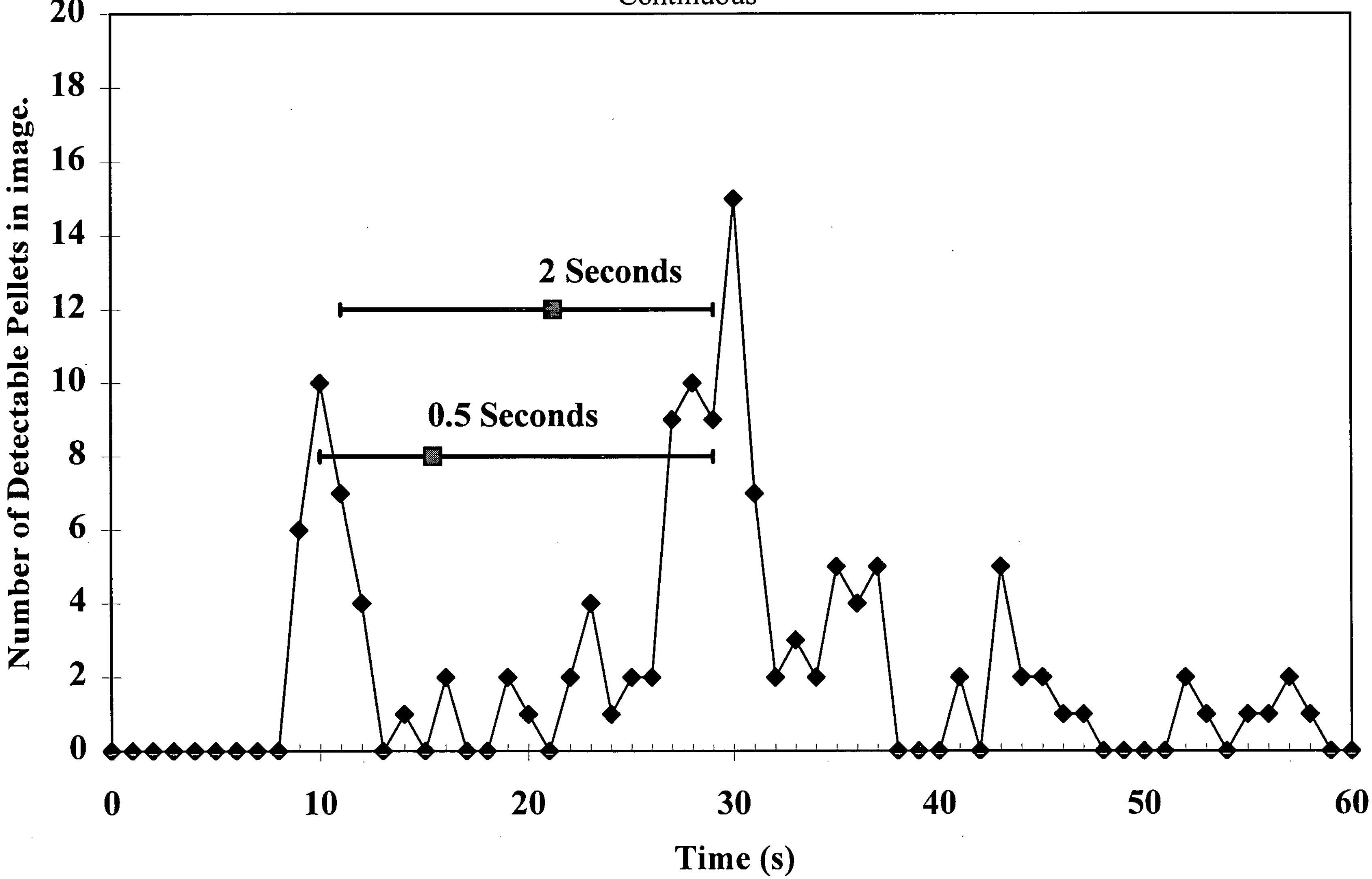
Sample: P, Date: June 28, 2000, Fish Size: 2.8kg, Stocking Density 11.1kg/m^3, Pellet Size: 9mm, Feeder Type: Burst



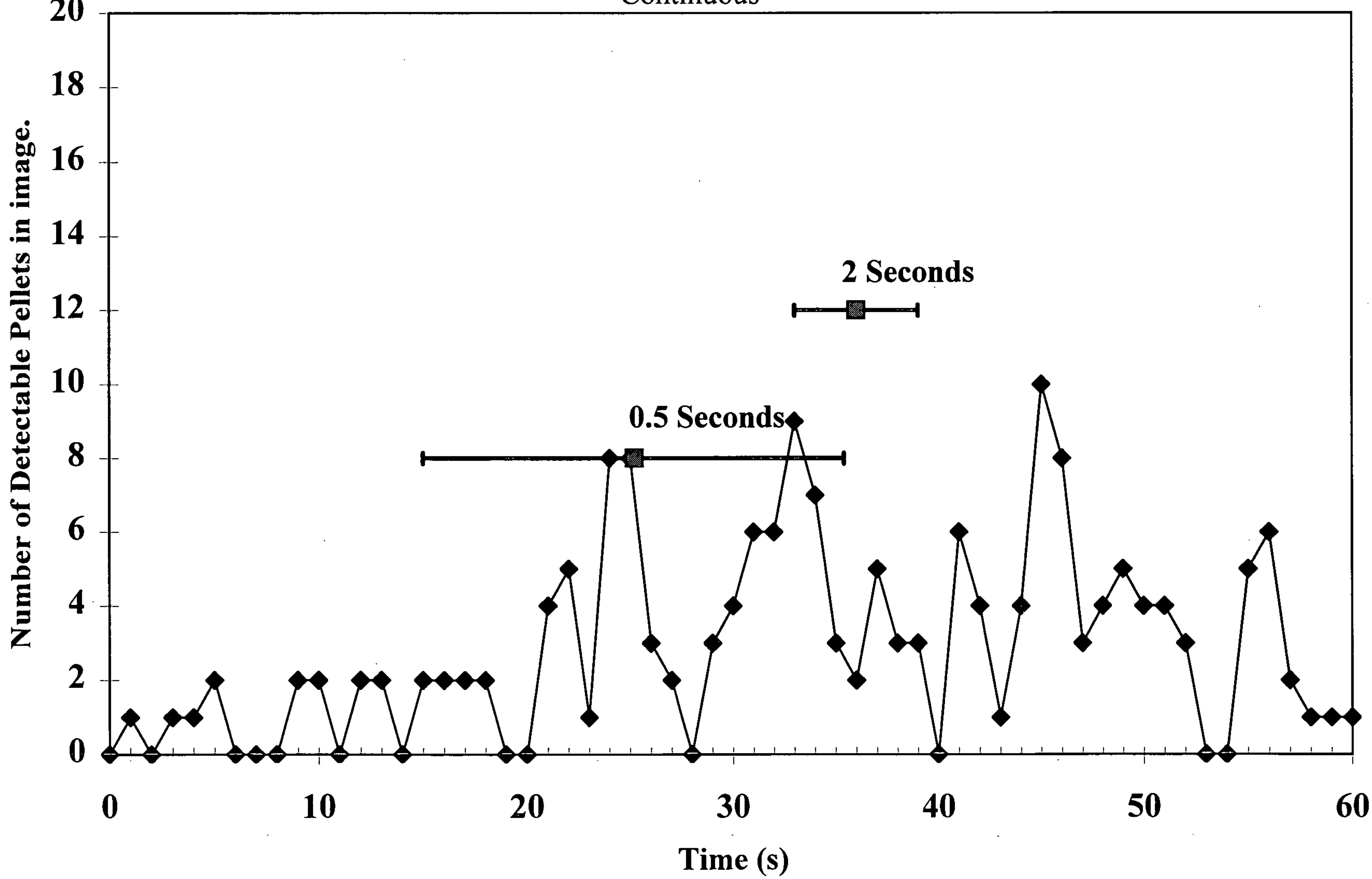
Sample: Q, Date: June 28, 2000, Fish Size: 4.0kg, Stocking Density 12.1kg/m^3, Pellet Size: 9mm, Feeder Type: Burst



Sample: R, Date: June 27, 2001, Fish Size: 4.5kg, Stocking Density 23.2kg/m^3, Pellet Size: 11mm, Feeder Type: Continuous



Sample: S, Date: June 28, 2001, Fish Size: 3.7kg, Stocking Density 20.3kg/m^3, Pellet Size: 11mm, Feeder Type: Continuous



Sample: T, Date: June 28, 2001, Fish Size: 4.8kg, Stocking Density 23.0kg/m^3, Pellet Size: 11mm, Feeder Type: Continuous