Report of the ICES Workshop on Methods for Estimating Discard Survival (WKMEDS)

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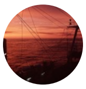

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Report of the Workshop on Methods for Estimating Discard Survival (WKMEDS)

17–21 February 2014

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Contents

1 Introduction

Research aimed at determining whether aquatic organisms, which have been caught and subsequently returned to the water, survive has been conducted over many decades. Although there have been reviews of the outputs from this work (e.g. Davis, 2002; Broadhurst *et al*., 2006; Revill, 2012; Uhlmann and Broadhurst, 2013), to date, there has been no comprehensive assessment of all the scientific methods and approaches that can be employed in meeting this aim. WKMEDS was initiated to establish and describe the methods of best practice to quantify the survival of aquatic organisms caught and returned to the water.

Relevant work on discard survival has been conducted in commercial and recreational fisheries around the world and the content of this report is designed to have global applicability. The catalyst for the formation of WKMEDS was the recent change in European Union fisheries policy, which has meant that there is particular need for guidance on how to investigate levels of discard survival. Article 15 of the reformed Common Fisheries Policy (CFP) Basic Regulation, which came into force on January 1st 2014, introduced a phased discard ban or landing obligation for regulated species. The policy includes a number of exemptions and flexibility tools. In paragraph 2(b) an exemption from the landing obligation is described for "*species for which scientific evidence demonstrates high survival rates, taking into account the characteristics of the gear, of the fishing practices and of the ecosystem*". To support any proposal for an exemption for selected species or fisheries, therefore, clear, defensible, scientific evidence for high discard survival rates are required. This has generated interest from various stakeholders in understanding the methods to generate discard survival estimates, and in the quality and robustness of the results from survival assessments.

There are practical and scientific limitations to all of the methods currently available for estimating discard survival (ICES, 1995, 1997, 2000, 2004 and 2005; Revill, 2012; Gilman *et al*., 2013). Consequently, there is a need for the provision of guidelines, and identification of best practice, for undertaking discard-survival assessments. In response to a request from the European Commission, through the Scientific, Technical and Economic Committee for Fisheries (STECF, 2014), to address this need for guidance, ICES established a Workshop on Methods for Estimating Discard Survival (WKMEDS), on 1st January 2014.

WKMEDS, chaired by Mike Breen (Norway) and Thomas Catchpole (UK), has been tasked to:

a) Develop guidelines and, where possible, identify best practice for undertaking discard survival studies (using the framework detailed in the report of STECF Expert Working Group EWG 13-16) (ICES WKMEDS, 17-21 February, 2014 workshop);

b) Identify approaches for measuring and reducing, or accounting for, the uncertainty associated with mortality estimates;

c) Critically review current estimates of discard mortality, with reference to the guidelines detailed in 1, and collate existing validated mortality estimates;

d) Conduct a meta-analysis, using the data detailed in 3, to improve the understanding of the explanatory variables associated with discard mortality and identifying potential mitigation measures; and

e) Based on ToR a) to d) a Cooperative Research Report (CRR) should be developed for consideration by the ICES Advisory (ACOM) and Scientific (SCICOM) committees.

This group will work by correspondence and a series of workshops to be held in 2014–2016. The first meeting was held on 17–21 February, 2014, at the ICES HQ in Copenhagen.

Objectives for the Guidance Notes (ToR a):

The primary objective of this document is to provide the user with an overview and guidance on the currently available methods for estimating survival rates of fish (and other animals) that are discarded as part of commercial fishing operations. By providing examples of best practice, it is expected that this guidance will enable the user to produce reliable estimates of discard survival.

This report will:

- describe the concepts behind assessing discard survival (Sections 2 and 3);
- describe three different approaches for estimating survival (vitality assessment, captive observation and tagging) (Sections 4, 5 and 6); and
- provide guidance on the selection of the most appropriate approaches and experimental designs, as well as how to integrate and utilize information from them, with respect to specific discard survival objectives (Sections 3, 7, 8 and 9).

Later versions of this report will cover in more detail:

- techniques for assessing survival using tagging and biotelemetry; and
- the most appropriate methods for analysing and reporting survival data.

It is assumed that the user of these guidance notes has sufficient scientific training, or at least access to suitable scientific support, to be able to conduct the techniques described in these notes in an appropriately systematic and disciplined manner. However, these guidance notes are intended also to be informative for other stakeholders associated with fishing (primarily fishers and managers) who wish to support and understand discard survival estimates.

Note on high survival

As well as describing and recommending how best to estimate discard survival, it is also recognized that stakeholders will also require guidance on the second element of the exemption – what constitutes "high survival rates". However, this is not the remit of WKMEDS and readers are directed to STECF EWG 13–16 (STECF, 2013). The STECF EWG concluded that the term “high survival” is somewhat subjective and that defining a single value cannot be scientifically rationalized. Therefore it is advised that assessing proposed exemptions on the basis of "high survival" need to be considered on a case-by-case basis, taking account the specificities of the species and fisheries under consideration.

2 Background

2.1 What are discards?

"Discards are the portion of a catch of fish which is not retained on board during commercial fishing operations and is returned to the sea" (Catchpole *et al*., 2005). The discarding process can be defined in terms of different phases i) capture by the fishing gear; ii) handling at the surface; and iii) release back to the water (Figure 2.1). During each of these phases a fish will be exposed to different influencing factors and injurious events that will effect is survival potential (see Section 7). A key task of a survival assessment is to ensure these main influencing factors and their variability are properly identified and described for the species and fisheries of interest (see Section 3).

The landing obligation explicitly mentions recreational fisheries and their potential impact on the fishery resources. Recreational fishers often practice catch-and-release (C&R), with release rates often exceeding 60% and dependent on many factors including legal restrictions and voluntary C&R (Ferter *et al*., 2013). While Member States are required to ensure that marine recreational fisheries are conducted in a manner compatible with the European Common Fishery Policy (CFP), there is also a large body of literature estimating post-release survival and explanatory variables. We would like to point out that the words 'discards' and 'releases' may often be used interchangeably and that the recreational knowledge base provides many examples of best practice for studying release survival.

2.2 What is discard survival?

Before discussing the most appropriate methods for measuring the survival of discards it is useful to consider what we mean by "survival". It can be defined as: *"The state or fact of continuing to live or exist, typically in spite of an accident, ordeal, or difficult circumstances"* (OED, 2014). However, there can be varying states of "survival" where, depending upon the stresses and injuries endured, individuals can be defined as having differing levels of "vitality" (Davis, 2010; Dawkins, 2004). Understanding and measuring these signs of vitality can be useful for predicting the likelihood of survival in fisheries biology (e.g. Benoit *et al*., 2010; Davis, 2010).

The opposite of survival is death, which is a more definitive state to identify. So typically when we measure the "survival" of organisms, after they have experienced a particular treatment, we in fact quantify the number of individuals that died, based on a measureable definition of death. More precisely, we usually measure mortality rates, which is the number of individuals that die over a defined period of time. The inverse of the mortality rate is the survival rate.

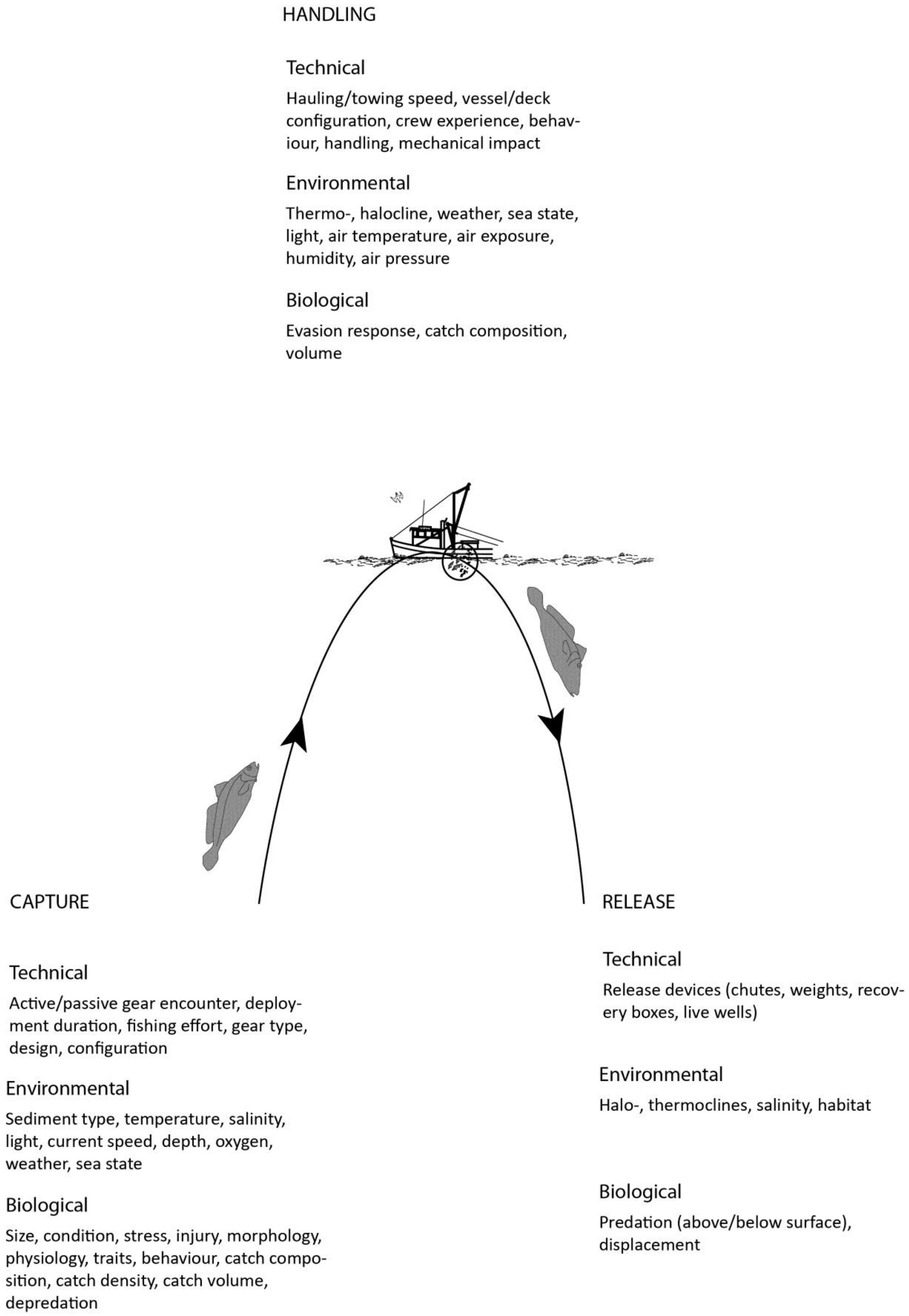


Figure 2.1. Stressors influencing the survival of captured-and-discarded organisms during fishing (adapted from Davis, 2002 and Broadhurst *et al.,* 2006).

2.3 Survival and time

Death is not normally an instantaneous process and some time will elapse between an initial exposure to a fatal stressor and the eventual cessation of life. Conversely, if observed long enough, any individual will die. Therefore, the time frame over which we make observations will have an important influence upon the estimated survival rate.

There is no standard time frame for conducting a survival assessment, as it depends upon the species in question and the nature of the fatal effects, as well as the logistical limitations of the investigation (Wassenberg and Hill, 1993). As such, in the scientific literature there is considerable variation in the observation periods used in different assessments and this had led to the evolution of generic time frames: 'immediate' (minutes to hours after treatment) and "delayed" mortality; where "delayed" mortality can sometimes described as 'short term' (days to weeks) or 'long term' (weeks to years). These are quite arbitrary and subjective terms that have potential to confuse, so should be used with caution. To this end, we recommend that survival estimates should always be presented in context to the time frame over which they were derived (e.g. "40% mortality, equating to 60% survival; 6 days observation").

2.4 Variability of discard survival estimates

A recent review of estimates discard survival rates summarized experimentally derived estimates with respect to species and fishery (Revill, 2012; see Appendix II for examples). The review shows that some estimates of survival vary considerably – in extreme cases between 0 and 100%. In such cases, there may be little practical use for discard survival estimates in managing the fishery because the conditions leading to discard mortality are so variable.

When presenting discard survival rates, it is important to consider that these are the summation of many individual deaths. Understanding the processes that led to the death of the individual is useful to interpret discard survival and key to learn how to increase it. The variability observed in discard estimates is driven by 1) the variability of the stresses experienced by the individual and 2) the biological characteristics and status of the individual.

1) Variability of survival from stressors

A fish or other animal will experience an array of different potentially injurious events, or stressors, throughout each phase of the capture process: i) **capture** by the fishing gear; ii) **handling** at the surface; and iii) **release** back to the water (Figure 2.1). In this context, an array of factors that could potentially influence discard mortality can be identified (see section 7). These can be classified into three broad categories: biological (e.g. species, size, age, physical condition, occurrence of injuries), environmental (e.g. changes in: temperature, depth, light conditions) and technical (e.g. fishing method, catch size and composition, handling practices on deck, air exposure; Davis, 2002). Each stressor and the additive effects of multiple stressors will influence the survival of an individual. The key stressors identified in the catch, handling and release phases, should be represented in the experimental design and resultant survival estimates (see section 9). Moreover, the survival rate derived from the experiment can provide information on the relationship between stressors and survival from which can sometimes be inferred fatal mechanisms (e.g. Ellis et al., 2012; Figure 2.2).

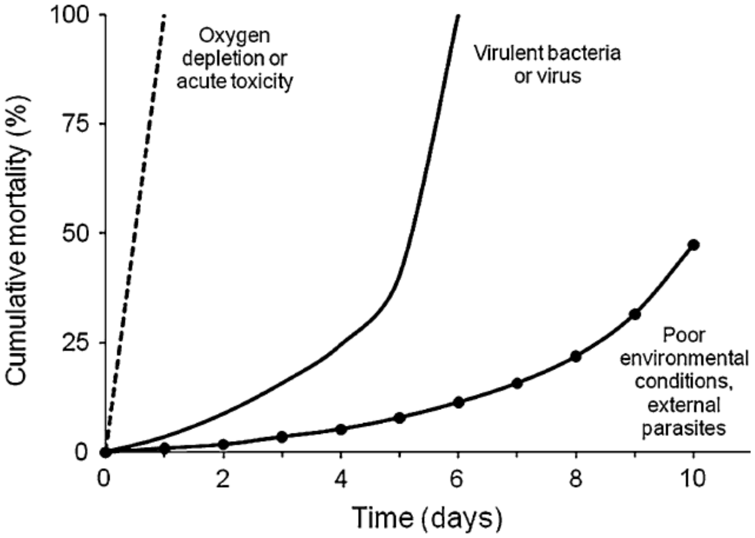


Figure 2.2. The rate of mortality can provide information on the relationship between stressors and death (from Ellis et al., 2012; redrawn from Wedemeyer, 1996).

2) Variability of survival from individual characteristics

Every organism has critical biological systems that maintain its vitality throughout its life. If any one of these systems permanently fails, the organism will die (Hillman, 2003). For a fish, these systems include the cardio-vascular, respiratory and neurological systems; the loss of any one of which will rapidly kill the fish (Roberts, 2012; Ellis *et al.*, 2012). There are other critical systems that if severely disrupted will significantly increase the likelihood of the fish dying, but maybe over a longer time period (i.e. hours to days), including: the osmoregulatory, metabolic, immunological, endocrinological and behavioural systems, for example (Roberts, 2012; Ellis *et al.,* 2012). The failure of these systems, or components of them, can happen for many different reasons, including: traumatic injury, physiological disruption or "stress", disease, and senescence (aging); or any combination of these. Furthermore, different individuals will have different capacities to endure systematic disruption, depending upon various different factors, including, age, size, physical condition, and sex. Therefore what simply manifests as the death of an individual can have numerous possible causes, mechanisms and time frames.

2.5 What are the benefits to studying factors that influence discard survival?

When discarding fish we can anticipate there will be common fatal mechanisms leading to the deaths of individual fish. Therefore, there are likely to be factors that can be correlated to the observed survival. When examined in reference to these influential factors, the variability among discard survival estimates can be better understood and explained (see Section 7).

3 Discard Survival Assessments

3.1 What is a discard survival assessment?

For the purposes of this report, an investigation, experiment or project that has a principle aim to quantify the survival of aquatic organisms after having been caught and released back to the water is referred to as a discard survival assessment.

3.2 Three Experimental Approaches

Here we describe the different experimental methods used to conduct a discard survival assessment with the aim to estimate discard survival. These are presented as three main approaches:

Vitality Assessment: where the vitality of the subject to be discarded is scored relative to any array of indicators (e.g. activity, reflex responses and injuries) that can be combined to produce a vitality score. Where these scores have been correlated with a likelihood of survival they can be used as a proxy for survival likelihood (see Section 4);

Captive Observation: where the discarded subject is observed in captivity, to determine whether it lives or dies (see Section 5); and

Tagging and Biotelemetry: where the subject to be discarded is tagged and released, and either its behaviour/physiological status is remotely monitored (via biotelemetry) to determine its post-release fate, or survival estimates are derived from the number of returned tags (see Section 6).

Sections 4–6 describe these approaches, including the principles behind each method, and their benefits and limitations. Before using estimates of discard survival in the context of fisheries management, consideration should be given to these limitations and potential sources of error. In isolation, each method has limitations which can restrict the usefulness of the survival estimates they produce. However, when two or more of these methods are combined there is clear potential for considerable synergistic benefits. The benefits from this integrated approach include: reducing resource requirements, increasing the scope of the investigation, as well as improving the accuracy, precision and application of the survival estimates. The mechanism of integration and the outputs that can be achieved through the integration of approaches are detailed in Table 3.1.

In general terms, vitality assessments give the proportion of discards that are dead at the point of discarding and a measure of vitality impairment; this can be presented as the potential for survival. The technique does not provide a survival rate per se but when combined with captive observation and/or tagging techniques it can generate a proxy to estimate survival across a representative range of conditions. Captive observations in isolation give a discard survival estimate that excludes predation, and one that relates only to the fishing conditions under which the individuals were captured and observed. But when captive observation is combined with vitality assessments, a survival rate (excluding predation) that is representative of the fishery can be generated. Similarly, the tagging approach in isolation provides a discard survival rate that relates only to the conditions under which fish were tagged. Tagging is the only approach that delivers a survival rate that is inclusive of predation and when integrated with vitality assessment (and potentially captive observation also), it provides the most complete approach to estimate a discard survival rate that is representative of a fishery.

3.3 Planning a survival assessment – an integrated approach

When planning and conducting a survival assessment, there several key steps and decisions to be made (see Figure 3.1):

A. Stakeholder involvement (see Section 3.4): the importance of involving stakeholders at all stages of designing, conducting and reporting of the survival assessments cannot be overstated. As well as providing invaluable information about the characteristics of the species and fisheries, it will also increase the value and uptake of the data from the assessment for the management of the respective fisheries.

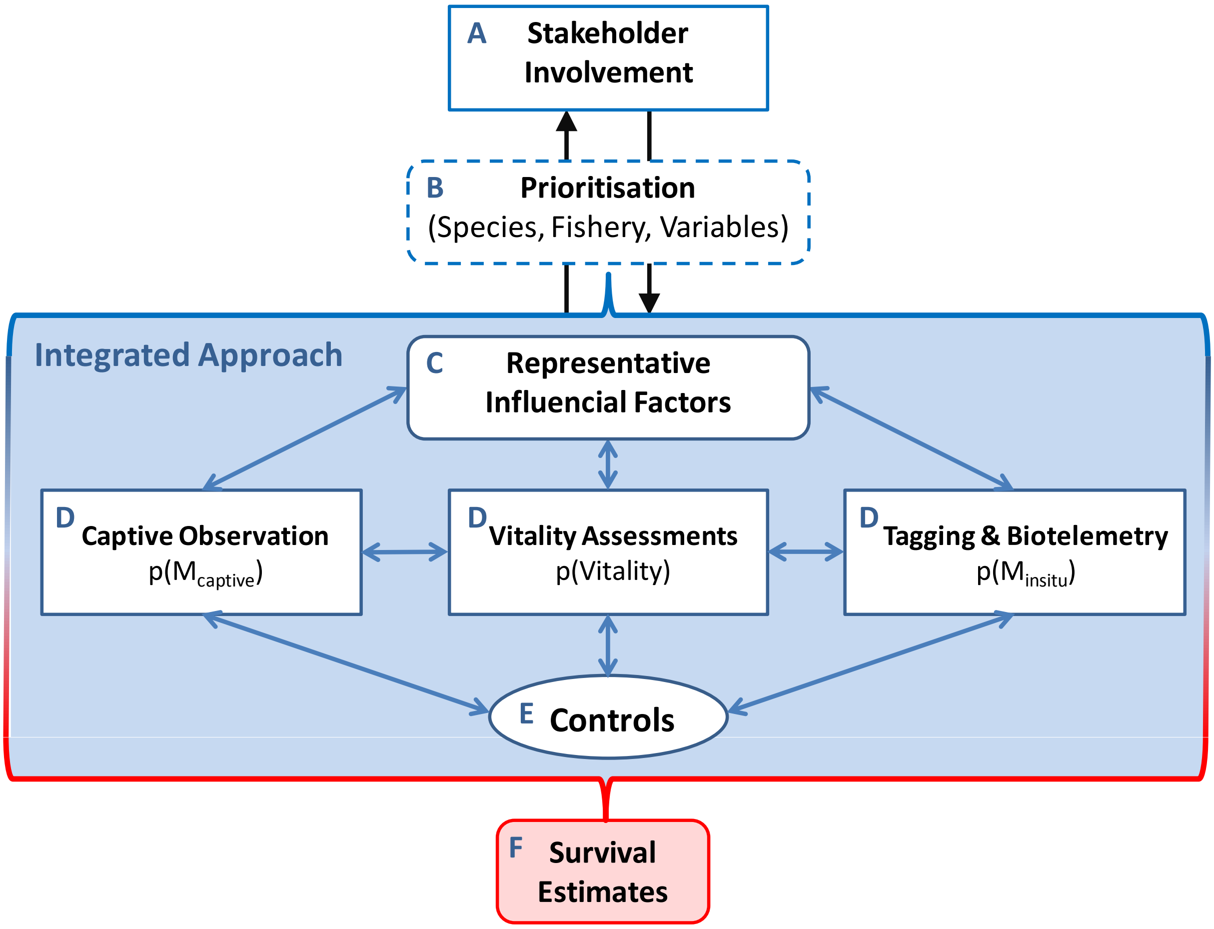


Figure 3.1. Overview of the Survival Assessment Process.

B. Prioritization - identify candidate species, fisheries & variables (see section 3.5): the choice of which species in which fisheries to study depends upon several criteria: existing survival information: the biological traits of the species, its population status, magnitude of discarding, fishery characteristics, environmental characteristics, socio-economic value of the fishery, available resources, and management policy. The process of prioritizing is unlikely to be simple and may involve a number of iterations, where results of preliminary studies inform the final choice.

C. Representative influential factors: A key step is to identify the most likely influential factors for the species and fishery of interest. This is done both conceptually, by using pathway analysis to identify the variables an organism is facing during the capture process (see Section 3), and by physically measuring these factors at each stage of the fishing operation: capture, handling and release (see Section 7); ensuring that the full range of their variability is described. Subsequent survival assessments will then ensure that the main factors, and their variability, are properly represented in the experimental design (see Section 7 and 9).

D. Selecting and integrating methods for estimating survival (see section 3.6): Selecting the most appropriate methods for estimating the survival of a particular species, or group of species, in a particular fishery will depend on the precise objective of the study (see Table 3.1). This will depend on many factors including the characteristics of the species and the fishery and the available resources. In section 3.6, we discuss the available options and what implications these will have on the application and utility of the survival estimates.

E. Using controls in discard survival assessments (see section 8): Including controls within the survival assessment informs the researcher on the factors influencing observed mortality. In cases where 100% of the treatment subjects survive, it can be inferred that there was no method induced mortality. Where survival is less than 100%, unless a control is employed, it cannot be determined whether mortality was associated with the treatment (having gone through the catch and discard process) or the experimental process (e.g. having been contained or tagged). Section 8, discusses the principles and uses of controls in the context of discard the survival estimates.

F. Analysing & defining survival estimates in discard survival assessments (see section 9):

When presenting survival estimates, important contextual details should be made explicit, as well as limitations and assumptions about the methods used that may introduce uncertainty in the estimates, for example:

- context - i.e. time frame / mortality rate, explanatory variables, sample size and level of replication;
- limitations and assumptions – i.e., restricted monitoring period, exclusion of predators, method induced effects; and
- uncertainty – i.e. estimate confidence intervals, suspected biases or impression.

The methods used to analyse survival data will, by necessity, influence the design of the assessments. This report provides a brief overview of the available techniques for analysing survival data (see Section 9); a subsequent updated report will provide more comprehensive guidance notes.

3.4 Involving Stakeholders

Results of discard mortality studies may have a large influence on fisheries management. For example, it may lead to an exemption of the landing obligation in EU fisheries, for certain fisheries or species which are assessed to have a high likelihood of survival. Therefore, it is essential that the studies are scientifically robust. To increase the acceptance of results, which are potentially not in the interest of the stakeholder, it is also important to involve the end-users in the whole process. If there are many uncertainties in the results, there may be discussions on their validity.

Because rates of discard mortality depend on a large number of factors (Section 7), discard mortality assessments are likely to show a considerable uncertainty in their results. Such uncertainties may invoke criticism about their utility by potential end-users of these mortality estimates, for example fisheries managers and fisheries organizations. In some cases, the results may even be disqualified and discredited. The risk of disqualification increases if the results are not what the stakeholders and managers had expected, or hoped for. This emphasizes the importance of managing realistic expectations in all stakeholders from the onset of the survival assessments. Fishers and managers may have unrealistic expectations of the results of the discard mortality studies (e.g. about the mortality estimates or about the influence on fisheries management).

If stakeholders and managers are involved in deciding on the objectives, the methods, and the outcome of the studies, this helps to gain and strengthen their commitment (Johnson & Van Densen, 2007; Kraan *et al.*, 2013). The prioritization of which fisheries and species shall receive the most attention should be made together (Section 3.5). The objectives (Section 3.6) need to be agreed upon and the methods, as well. When the results are available, it is helpful to discuss those with the involved stakeholders and managers.

3.4.1 Self-sampling by Fishers

A way to involve fishers is to train and involve them in collecting data. Vitality assessments are potentially a part in which fishers can help collect valuable information. They are low cost, relatively quick to conduct, so they will not disrupt the fishers' normal routine too much. To make sure that protocols are followed consistently there should be regular quality assurance.

No literature is known on validation of self-sampling data from survival studies. There are some papers on validation of other types of self-sampling data (e.g. Roman *et al.*, 2011, Walsh *et al.*, 2002), but these do not apply to survival estimates. Advantages are that fishers are so often at sea, that they can collect a lot of information in a very cost efficient way. Besides that, it will create a larger commitment to generating discards survival estimates. A disadvantage is that there is something at stake for the fishers. Even if the fishers and scientists are convinced that the self-sampling fishers did not manipulate the results, there may be other parties that may think they did.

3.5 Prioritization - Identifying Candidate Species, Fisheries & Variables

3.5.1 Criteria for Setting Priorities

There is likely to be a large number of candidate species and fisheries for which estimates of discard mortality will be desired in the context of a possible exemption to the landings obligation as described in the EU Common Fisheries Policy. To even produce coarse estimates for all of them is going to go beyond all scientific capacities and resources. A process for establishing priorities will therefore be required. Conceptually, there appears to be at least seven distinct criteria that could be considered in setting priorities, two of which are related to the survival potential of discards and can be informed by the information presented in this report (see 1 and 2 below). These seven groups are presented below in no particular order of importance.

1) Biological characteristics of the discarded individuals of interest. Physical and physiological characteristics of individuals can affect their susceptibility to dying as a result of the capture, handling and discarding process. Susceptibility varies among species, and generally varies inversely with body size within species (Broadhurst *et al.*, 2006; Uhlmann and Broadhurst, 2013). Relative susceptibility is known for certain species or taxonomic groups (e.g., Revill 2012), while for others it can be inferred roughly from their biological traits (e.g., Benoît *et al.*, 2013)(Section 7). Alternatively, assays of species susceptibility can generally be conducted rapidly and efficiently in the field (section 4).

2) Characteristics of the fishery. The survival prospects of a fish are influenced by the capture (e.g. gear type) and catch handling (e.g. handling time) characteristics of the fishery, and the environmental conditions experienced by fish from the time they are captured to the time they return to their habitat following discarding (Section 7). In the absence of other information, the effects of the fishery characteristics can be considered additive at the priority setting stage. A preliminary survey of mortality proxies or indicators from the fishery could provide an indication of potential discard mortalities (Section 4).

3) Population status. There are numerous reasons why population status might affect priority setting. For example, there may be a desire to favour depleted species if a successful live release policy is expected to improve the rate or likelihood of recovery. In other instances there may be evidence that mortality of a particular population component (e.g., age, size or sex) affected by discarding has a disproportionate effect on the productivity of the stock. In such a case, successful live release may be a particularly effective manner of enhancing productivity. Information on status will be generally available from stock assessment reports.

4) Magnitude of discards or discard rate. The absolute amount of fish discarded and the proportion of the catch that is discarded (discard rate) may both be pertinent considerations. When considered in light of population status, they will reflect discard related mortality and the fraction of fishing mortality that is potentially comprised of discard loss. In this respect they can be used to evaluate the potential benefits of different levels of discard survival; information should be available from fishery monitoring data. The amount of discarding is also relevant from the perspective of how much extra sorting time and storage space would be taken up on board a vessel, which may increase the costs associated with an obligation to land that particular species.

5) Socio-economic value. The socio-economic value of a fishery to the regional or national economy may influence its prioritization, where suitably resilient species form part of the unwanted catch.

6) Policy implications. A discussion of the policy implications of mandatory landing exemptions that might affect the relative priority of a fishery for detailed assessments is beyond the scope of this report. Relevant considerations might include prioritizing fisheries such as to minimize the landing of fish for which there is little or no market and which must be disposed of, and favouring the live release of incidentally caught charismatic species. Or identifying “choke” species which may be discarded at times in large quantities, but quota restrictions may imply that fishing may be cut short.

3.6 Selecting methods for estimating survival

A synthesis of the approaches currently available, which are recommended to meet specific objectives to estimate discard survival is provided in Table 3.1. This table can be viewed either as means to identify a single approach to meet a specific objective or as a stepwise process, from 1 to 6, that may be applied to a project. In general, the approaches taken from first to last increase in the level of resources and time required to achieve the stated goal. The outputs that can be generated from the approaches range from providing estimates of the proportion of discards that appear dead or impaired at the point of discarding under particular conditions (referred to as "survival potential") (1), to generating a discard survival rate for a population that is representative of a fishery (management unit), including the influence on survival of selected variables (6).

Here the suggested, currently available, approaches considered most suitable to deliver specific objectives are described. It is assumed that the species, size classes and the fishery (management unit) of interest for discard survival investigation has been selected. The approach recommended is based on generating results that will meet the specific objective using the most cost-effective approach and in the shortest time period. Before beginning an assessment, expectations should be expressed and agreed to by those conducting and funding the work, as well as those managers and stakeholders who plan to use the outputs from the assessment.

1. To estimate immediate discard survival potential for particular conditions

The recommended approach here is to perform vitality assessments at the point of discarding, in isolation, i.e. without considering/representing the range of conditions under which the management unit operates. This approach is best used to establish whether further investigation for a species in a specific fishery is warranted. Where the vitality assessment includes a criterion defining dead specimens, this approach provides an approximate estimate of the proportion of individuals that are dead at the point of discarding. However, no inferences can be made on how long any living specimens will survive beyond this point. Also, imprecision in the definition and identification of dead individuals will be reflected in uncertainties in the survival estimates (see section 4). The findings from this approach can only be associated with the particular fishing conditions under which the individuals were observed; the influence on survival of any variability within the fishery remains unknown. Using the vitality assessment approach also generates a measure of impairment as the proportion of discards at each defined vitality level, data that can be utilized in subsequent investigations.

Table 3.1 - An overview of possible objectives for a survival assessment and the recommended approaches

Objective (for the selected species, variables & management unit)	Suggested approach	Resource Implications
To estimate discard survival potential for particular conditions	Vitality assessment onboard commercial vessel(s), with targeted observations of the factors that affect mortality.	Personnel: Trained observers & fishers Specialist equipment: None Time frame: hours to days for field trials
To estimate discard survival potential that is representative of the management unit	Vitality assessments onboard commercial vessels during representative range of conditions	Personnel: Trained observers & fishers Specialist equipment: None Time frame: hours to days for field trials
To estimate discard survival rate, excluding predation, for particular conditions	Captive observation of individuals under particular conditions	Personnel: Experienced researchers & fishers Specialist equipment: Containment facilities (e.g. aquaria & sea cages) Time frame: days to weeks for monitoring period
To estimate discard survival rate, excluding predation, representative of the management unit	Vitality assessments onboard commercial vessel(s) during a representative range of conditions combined with captive observation of individuals representing the various vitality levels to generate an overall weighted-mean survival estimate	Personnel: Trained observers, Experienced researchers & fishers. Specialist equipment: Containment facilities Time frame: days to weeks for monitoring period
To estimate discard survival rate, including predation effects, for particular conditions	Tagging/biotelemetry onboard commercial vessel(s) under particular conditions	Personnel: Experienced researchers & fishers. Specialist equipment: Tags Time frame: days to months/years for monitoring
To estimate discard survival rate, including predation effects, representative of the management unit	Option 1: Vitality assessment onboard commercial vessel(s) during representative range of conditions combined with tagging/biotelemetry of individuals representing the various vitality levels onboard commercial vessel(s) to generate an indirect survival estimate	Personnel: Trained observers, Experienced researchers & fishers. Specialist equipment: Tags Time frame: days - months/years for monitoring
	Option 2: Vitality assessment onboard commercial vessel(s) during representative range of conditions combined with captive observation (to estimate short term mortality) and tagging/biotelemetry (to estimate conditional long-term mortality) of individuals representing the various vitality levels onboard commercial vessel(s) to generate an indirect survival estimate	Personnel: Trained observers, Experienced researchers & fishers. Specialist equipment: Tags, Containment facilities (e.g. aquaria & sea cages) Time frame: days to months/years for monitoring

2. To estimate immediate discard survival potential that is representative of the management unit

Here the recommended approach is to perform vitality assessments at the point of discarding, across the range of representative conditions under which the management unit operates. This is an extension of (1), in that it provides an approximate estimate of the proportion of individuals that are dead at the point of discarding, across a representative range of conditions, i.e. accounting for any variability of the fishery. Again, as in (1), the vitality assessment should include a criterion defining dead specimens. The result is representative of the management unit and the relative influence of selected variables on vitality impairment can be established.

3. To estimate discard survival rate, excluding predation, for particular conditions

When the objective is to estimate the survival rate for particular conditions and predation is not considered an important or priority factor (3), then captive observation under defined conditions is the recommended approach. This approach provides a discard survival rate that excludes the effect of predation. This survival estimate is representative only of the particular fishing conditions under which the individuals were captured and observed. When using this technique, it must be acknowledged that the effect of captivity upon the experimental subjects may underestimate survival, while the exclusion of predation effects may overestimate it.

4. To estimate discard survival rate, excluding predation, representative of the management unit

Where a discard survival rate is required that is representative of the management unit, and predation is not considered an important or priority factor, vitality assessments across a representative range of conditions for the fishery combined with captive observation is suggested. Conducting sufficient captive observation experiments to cover the full variability of conditions displayed by a fishery and species is practically difficult and expensive. Instead, the variability of vitality levels for discarded individuals can be described (as in objective 2). In addition, estimates of survival for the different vitality levels can be calibrated using captive observation (see section 4). These can then be combined to produce a proxy estimate of survival that should be representative of conditions in the fishery, excluding the effect of predation. This technique also gives the relative influence on discard survival (excluding predation) of selected variables. By applying the captive observation results to generate survival estimates, it must be acknowledged that these may be underestimated due to captivity effects, while the exclusion of predation effects may overestimate survival.

5. To estimate discard survival rate, including predation effects, for particular conditions

When the objective is to estimate discard survival, for particular fishing conditions, that includes predation effects, the tagging/biotelemetry approach is suggested. The findings from this approach can be associated only with the particular fishing conditions under which the individuals were captured and tagged. The survival estimates may be biased to the extent that the capture and handling conditions experienced by tagged discards may not reflect the conditions experience by all discards in the fishery, also there may be a method induced mortality due to the tagging procedures.

6. To estimate discard survival rate, including predation effects, representative of the management unit

Investigators will often start with the ambition to deliver the most comprehensive objective, that is, to estimate a discard survival rate that includes predation effects and is representative of the selected management unit (6). This may be unrealistic because this is likely to require substantial resources and will take considerable time to achieve.

Here we suggest two options; the first integrates vitality assessments with tagging, while the second integrates vitality assessments, tagging and captive observation. Tagging a sufficient number of individuals to cover the variability of conditions displayed by a fishery is practically difficult and expensive.

Option 1 – Vitality assessment and tagging/biotelemetry:

Survival is estimated based on tag return rates specific to each vitality level, as determined for individual tagged fish prior to release. These conditional survival rates are in turn combined with the frequency distribution of vitality-levels to estimate a survival rate reflective of conditions in the fishery. This approach assumes that the effect of the conditions experienced by fish during capture and handling are reflected in the observed distribution of vitality levels. These conditions should include all types of stressors observed in the fishery of interest, but not necessarily all levels of each stressor type. The tagging does not need to be representative of all conditions, but does need to include a sufficient number of tagged discards for each vitality level. This approach can provide representative discard survival estimates across the full management unit and include the relative influence of selected variables.

Option 2. Vitality assessments, captive observation and tagging/biotelemetry. The second option is an integration of all three general methods, vitality assessments from a representative range of conditions, combined with captive observation and tagging/biotelemetry techniques. Where captive observation has been investigated previously, these data can be integrated with newly acquired data from tagging work. This option will be selected where data have been generated already or when conducting less tagging work is preferred. The information given above for Objective 4 and Objective 6 (option 1) are relevant.

A mechanism for integrating the data from these approaches is suggested in section 9. An important consideration when combining approaches is to ensure that the survival estimates are used and interpreted correctly. An estimate derived (directly or indirectly) from results of a captive observation study can be used to establish discard survival rates that exclude predation, while that derived from results of a tagging can provide discard survival rates that include predation.

4 Vitality Assessment

4.1 Defining and measuring "vitality"

Vitality is an abstract property that relates to an organism's survival potential. A vital organism will be healthy and unstressed, whereas at the other extreme, mortality occurs when an individual's vitality reaches zero. Certain visual signs such as major injuries or impaired responses may reflect diminished vitality, in turn reflecting an increased risk of mortality (Dawkins, 2004).

Measurement of aquatic animal health and welfare has been hampered by a lack of real time field methods that are easy and inexpensive to use (Morgan and Iwama 1997; Huntingford *et al*., 2006). A direct and economically feasible approach to the problem is to visually assess animal status, or vitality, by measuring characteristics of whole animals such as activity, responsiveness, reflex impairment, and injury. This notion underlies the use of vitality assessment in understanding and predicting discard survival and mortality.

Vitality assessment can be used directly to explain variation in animal health associated with different fishing stressors. Measures of vitality impairment can be used as an indicator for discard survival, by calibrating them with survival likelihood estimates of specimens with known levels of vitality using captive observation studies (see section 5) and/or tagging/biotelemetry studies (see section 6). For example, reflex impairment (i.e. RAMP, reflex action mortality predictor) has been used to assess vitality and predict mortality in a variety of taxa, including crabs, prawns (Stoner, 2012), fish (Humborstad *et al*., 2009; Davis 2010; Campbell *et al*., 2010; Barkley and Cadrin, 2012; Raby *et al*., 2012) and turtles (LeDain *et al*., 2013).

4.2 An Overview of Vitality Assessment Methods

This section describes three simple and practical techniques for assessing the vitality of an animal discarded from a fishing operation. These techniques visually assess the subject prior to the point of release, but vary in their approach with respect to their applicability to describing the effects of the various stressors the subject may experience during the discarding process, as well as the resolution of their description of vitality. Selection of the most appropriate technique will therefore depend upon the objectives of the assessment and the intended use of the data.

i) Coarse mortality indicators (e.g. Time To Mortality, TTM)(Section 4.3): provide a coarse measure of the sensitivity of different species (or subgroups of) to specific discarding related stressors, most notably air exposure. Differences in the responses by different species, or subgroups, exposed to the same stressor can then be used to rank them with respect to their relative influence of discard mortality. This provides a quick and simple method for identifying species which have a greater likelihood of surviving discarding, but does not quantify the survival rate.

ii) Semi-quantitative assessment (SQA)(Section 4.4): uses rapid assessments of specific criteria (e.g. injuries, activity) under commercial conditions to provide a scored index of the subject's vitality. The quantifiable index can be used to describe the variation in vitality for a population over different discarding conditions. Where the different levels of the index have been calibrated with survival likelihood (see Section 4.6), this approach can be used as a predictive tool for estimating discard survival.

iii) Qualitative Vitality Assessment (QVA)(Section 4.5): is a quantitative vitality index, with increased resolution and objectivity, but also complexity, compared to SQA. It can be used in isolation, just as SQA, to collect information about the vitality of specimens under varying environmental, technical and biological conditions. The higher resolution of the vitality data makes this index well suited for investigating the influence of these variables on mortality. As with SQA, when calibrated with direct estimates of survival likelihood, the index scores can be used as a predictive tool for estimating discard survival.

4.3 Coarse Mortality Indicators (e.g. Time to Mortality, TTM)

The time required to induce mortality, or time-to-mortality (TTM), estimates the time at which 50% of individuals in a species are expected to die, based on observations of individual fish exposed to fishing related stressors (Benoît *et al.*, 2013). Individuals are monitored from when they are first exposed to the stressor (e.g. exposure to air) to the time when death is confirmed. In this manner, a large number of observations can rapidly be obtained from experimental subjects. Species, or subgroups, can then be ranked with respect to their relative risk of discard mortality, based on differences in the responses to the same stressor.

The measurable endpoint, "death", should be clearly defined using unambiguous criteria to assess the status of the individual (e.g. Benoît *et al.*, 2012; Davis, 2007). For some species that are naturally immobile and/or unresponsive (e.g. "tonic immobility" in some shark species), "death" can be challenging to identify quickly.

4.3.1 Applications for Coarse Mortality Indicators

This approach has been applied to animals caught during scientific surveys (Benoît et al, 2013), where individuals were monitored from the time the catch was brought aboard to the time when death is confirmed. The length of time that fish are kept out of water has been shown to correlate with discard survival rates from larger field studies (Benoît et al, 2013). This is presumably because the time spent on deck, exposed to air and associated hypoxia, is one of the most important factors influencing discard survival (e.g., Davis, 2002; Broadhurst *et al.*, 2006; Benoît *et al.*, 2010, 2012; see Section 7). Consequently, the relative susceptibility of different species to discard mortality could be assessed by determining their relative resilience to hypoxia.

In this manner, TTM estimates may provide a useful indicator of the risk that discard mortality may pose for a species or subset of species (e.g., size class). This simple metric could provide useful information when priority setting for science and management, in what might otherwise be a data-limited situation.

The other principal use of the TTM approach is in studying the technical, biological, and environmental factors that affect discard mortality (Benoît *et al.*, 2013). TTM studies can be designed to include exposure of individuals to factors other than hypoxia that may be important stressors in a variety of fisheries (e.g., temperature, injury, fatigue). The standardized setting of a scientific survey in which TTM observations can be obtained provides a useful framework for interspecies comparisons and size-based comparisons, and for disentangling the role of factors affecting mortality.

4.4 Semi-Quantitative Vitality Assessment

Semi-quantitative assessments (SQA) of vitality aim to produce observations that can be obtained rapidly for individuals (within 5–10 seconds) by trained fishery observers during commercial fishing operations. SQA frameworks have been applied to various species and fisheries and all are based on a notion of quantifying vitality (e.g., Hoag, 1975; van Beek *et al.*, 1990; Kaimmer and Trumble, 1998; Laptikhovsky, 2004; Hueter *et al.*, 2006; Benoît *et al.*, 2010). Most of these frameworks are based on ordinal categories (classes) that encompass injury severity, fish activity or a rough evaluation of reflex impairment (e.g., Table 4.1).

Degrees of injury, activity, and reflex impairment have been individually shown to be good predictors of eventual survival (Davis and Ottmar, 2006; Humborstad *et al.*, 2009; Davis, 2010), as have vitality scores in both tagging (e.g., Hueter *et al.*, 2006; Richards *et al.*, 1995; Kaimmer and Trumble, 1998) and captive observation studies (e.g., van Beek *et al.*, 1990; Benoît *et al.*, 2010, 2012).

4.4.1 SQA Method

Typically, SQA frameworks are based on three to five ordinal vitality classes that are defined at one extreme as characterizing uninjured, very lively and responsive fish, and at the other extreme, severely injured (externally) and unresponsive (moribund) individuals.

Table 4.1. Example description of the codes used by onboard observers to score the pre-discarding vitality of individual fish (from Benoît *et al.*, 2010).

Vitality	Code	Description
Excellent	1	Vigorous body movement; no or minor[a] external injuries only.
Good/ Fair	2	Weak body movement; responds to touching/prodding; minor[a] external injuries.
Poor	3	No body movement, but fish can move operculum; minor[a] or major[b] external injuries.
Moribund	4	No body or opercular movements (no response to touching or prodding).

[a] Minor injuries were defined as 'minor bleeding, or minor tear of mouthparts or operculum (≤10% of the diameter), or moderate loss of scales (i.e. bare patch)'.

[b] Major injuries were defined as 'major bleeding, or major tearing of the mouthparts or operculum, or everted stomach, or bloated swimbladder'.

Observations in a SQA are made on individual animals. An individual is selected from the catch and is briefly monitored. During that interval, the observer looks for obvious external injuries evidenced by tearing of the tissues, bleeding or scale loss, in addition to external evidence of barotrauma, the degree of body movements including ventilation, and the presence of reflex responses. The process of selecting an individual and manipulating it while scanning for injuries is sometimes enough to elicit a reflex response (e.g., body movements, flaring of the operculum or fins, gagging). In these instances, the observer will have all of the evidence required to attribute a vitality score. Otherwise, the observer will need to attempt to elicit a reflex response. Gently depressing the fish's eye or belly, or prodding the fish, has been used to this end. Continued absence of response leads to a classification of moribund.

Given well established relationships between the duration of air exposure and mortality (and therefore impaired vitality), the timing of SQA observations is paramount and should be made around the time that discarding normally occurs. This may be as fish are brought aboard, for example in fixed gear fisheries in which individuals are sequentially removed from the gear and discarding decisions are normally made at removal. Alternatively, it may occur some time after the catch is brought aboard in fisheries in which the total catch is assembled and sorted prior to discarding (e.g., trawl fisheries), where organisms for SQA are randomly selected throughout the sorting process. Catch processing in beam trawling for example, was shown to vary between 12 and 30 min (Depestele *et al.*, 2014).

4.4.2 Defining Assessment Criteria

By necessity, criteria for SQA need to be easily interpreted and applied. However, to be useful they must be responsive and specific to differences in vitality and should be obtainable in a consistent manner between observers and over time. Ideally the suite of observed characteristics used to score vitality should be small, easily memorized, and quickly assessed. For most applications, the characteristics used to categorize the degree of injury, fish activity, and reflex impairment can be generic to a range of species caught in a range of fisheries (e.g., Benoît *et al.*, 2010; Table 4.1). Alternatively, they can be tailored to a specific situation if there are particular characteristics of discarded individuals for which mortality consequences are known or suspected (e.g., Trumble *et al.*, 2000). For example, there may be specific injuries of hook-caught fish related to tearing of mouthparts or the alimentary canal with differential impacts on mortality, or there may be species-specific responses that can discriminate different degrees of vitality impairment.

Table 4.2 Example studies applying SQA and the number of vitality categories selected.

Species (group)	Reference	Number of categories
Nephrops	Méhault et al. 2011	3
Nephrops	Ridgeway et al. 2006	2
Alaskan crab	Stevens, 1990	3
Shark	Manire et al. 2001;	5
Shark	Hueter et al. 2006	5
Rays	Enever et al. 2009	3
Sharks, rays & chimaeras	Braccini et al., 2012	4
Fish	Benoît et al., 2010	4
Pacific halibut	Richards et al., 1995;	3
Pacific halibut	Trumble et al., 2000	3
Pacific halibut	NOAA Fisheries 2014	4

The number of categories used to classify or score vitality constitutes a trade-off. The consistency of application by observers is likely to decline as the number of categories increases and the differences between categories become more subtle; while the precision (but not the accuracy) of SQA-derived mortality estimates will increase with the number of categories. Discard mortality of Pacific halibut (Hippoglossus stenolepis) was initially quantified using a five-category vitality scheme (Hoag, 1975). However, later analyses indicated that grouping into three categories reduced the variance of the vitality data and improved the precision of category-specific survival estimates based on tagging (Clark *et al.*, 1993). Other studies have found clear survival differences between categories in three- to five-category schemes (e.g., Van Beek *et al.*, 1990; Laptikhovsky, 2004; Hueter *et al.*, 2006; Benoît *et al.*, 2010), suggesting that the optimum likely lies in this range. Consequently, it may be advisable to plan a study with a number of vitality categories that is on the upper end of this range, and to contemplate merging categories at the data analysis stage.

4.4.3 Applications for Semi-Quantitative Assessment

An SQA of vitality is readily applied in the field (e.g. on-board commercial fishing vessels) along with the usual activities of a fisheries observer. This constitutes the greatest advantage of SQA because, to the extent that observers are monitoring discard amounts in a manner that is representative of conditions in the fishery, vitality monitoring will also be representative. In turn, conditional estimates of survival with respect to vitality level obtained from captive observation or tagging can be combined with the vitality observations to produce a weighted estimate of survival that is representative for that fishery (e.g., Richards *et al.*, 1995; Hueter *et al.*, 2006; Benoît *et al.*, 2012)(see Section 4.6). In a unique example, Pacific halibut SQA vitality scoring and prediction of discard mortality has been validated with tagging studies and is used in active fisheries observer programs to estimate mortality rates in assessment models and stock management (Richards *et al.*, 1995; Trumble *et al.*, 2000; NOAA Fisheries 2014). This presents a particularly effective method for representative discard survival estimation. Variability of discard vitality between fishing events is likely to be reflected in variability of vitality scores. Quantifying this variability will also be cost-effective, particularly where existing observer programs are in place. Updating mortality estimates as conditions in a fishery change over time is therefore feasible. This however is dependent on having no changes in the stressor types present in the fishery compared with those in the original study that estimated vitality-correlated survival (see Section 4.6).

Vitality SQA observations also hold promise for inferring the potential for long-term discard survival. For example, it appears reasonable to assume that adversely affected discarded fish that have been rendered impaired and inactive will be at greater risk of predation due to compromised evasion abilities. Likewise, the potential for disease may increase with the degree of physical injury. Relationships between vitality score and predation risk or disease-related mortality could be quantified to infer preliminary estimates long-term survival. For example, a tagging study for Pacific halibut indicated a reduced number of tag returns with increasing severity of hook removal (Kaimmer and Trumble, 1998).

Outputs from SQA can also inform on how vitality scores are influenced by various factors, biological (e.g., size), technical (e.g., handling time) and environmental (e.g., depth, temperature) (e.g., Richards *et al.*, 1994; *Benoît et al.*, 2010). Understanding how various factors affect the likelihood that a discarded fish would fall into a particular vitality class can facilitate the planning of management measures aimed at increasing discard survival. Furthermore, if calibrated estimates of survival with respect to vitality are available, then empirical relationships between semi-quantitative vitality scores and explanatory factors can be used to predict survival for situations where there are no vitality observations (e.g., Benoît, 2013).

4.5 Quantitative Vitality Assessment (QVA)

Quantitative vitality assessment is based upon the RAMP vitality assessment method (Reflex Action Mortality Predictor), which was developed to improve the resolution and objectivity of vitality impairment observations and mortality prediction in stressed animals, based on reflex impairment (Davis, 2010). Further studies have shown the utility of including scoring for injury in the RAMP assay to make it more inclusive of sources for vitality impairment (Campbell *et al.*, 2012; Nguyen *et al.*, 2014). QVA can be used in isolation, just as SQA, to collect information about the vitality of specimens under varying environmental, technical and biological conditions. When calibrated with direct estimates of survival likelihood, QVA scores can also be used as a predictive tool for discard survival.

The approach aims for a more thorough description of vitality than SQA, by capturing as much information about reflex impairment and injury as is practicable in field settings (Davis and Ottmar, 2006). In comparison to SQA it can be argued that QVA is a more objective approach with higher resolution in its vitality assessment. That is, QVA generally tests more criteria (reflex actions and injury) and scores using only presence or absence. However this is at the expense of a longer period of observation per individual fish (30-60 seconds compared to ≤10 seconds in the SQA).

4.5.1 QVA Methods

QVA is based on scoring the presence or absence of behavioural reflexes and injuries. Reflex responses, which are innate involuntary actions or responses to a stimulus (Berube *et al.*, 2001), can be quantified as present or absent after stimulating the subject using touch, light, sound, or gravity. Reflex actions are used because they are innate fixed action patterns that are directly related to vitality, without being confounded by the effects of other factors (e.g. size, motivation, sex). Some commonly used reflexes studied in the RAMP method that can be used in QVA include tail grab, body flex, head complex, vestibular-ocular response, and orientation (Raby *et al.*, 2012).

Injury is scored because of its direct relationship with trauma and potential infection, and thus mortality. Different types of injury can be simply quantified as present or absent. Commonly observed injury types include barotrauma (Hannah *et al.*, 2008) and wounding from hooking, abrasion, and predation (Trumble *et al.*, 2000).

4.5.2 Selecting Assessment Criteria

Different reflex actions, barotrauma symptoms, and injuries can be used as assessment criteria, depending on characteristics and life-history traits of the subject species (see Appendix III for examples). To select the most appropriate reflexes for the subject species, animals in the best possible condition are collected in the field or held in captivity. They are then examined using a range of possible reflexes (see Appendix III) to determine which reflexes respond most consistently, from individual to individual, to the range of potential stimuli available to the observer (e.g. touch, light, sound and gravity). Reflexes can be tested in unrestrained or restrained animals, although unrestrained animals are more easily assessed on board vessels. Tests can be adapted to experimental or operational conditions needed in particular situations and for specific species. As many different reflexes and injury types are measured as is practicable and appropriate; in order to describe stress effects on a wide variety of neural, muscle and organ systems.

Selection of the most appropriate injury types, as for SQA, is highly species and fishery dependent (see Section 4.4.1). This will require some *in situ* observations to determine the most common and relevant injuries occurring for particular species under a range of conditions in the fishery, including technical (i.e. gear and handling related injuries: abrasion, hooking/puncture wounds) and environmental (e.g. barotrauma, desiccation, freezing). Moreover, the injuries should be easily identifiable and clearly debilitating for the specimen.

4.5.3 Calculating a QVA Score

Calculating QVA score for reflex impairment and injuries follows the "rule of doubt". A reflex action is scored not impaired (0) when strong or easily observed, or impaired (1) when not present, weak, or there is doubt about its presence. An injury (including barotrauma) is scored absent (0) when not present or there is doubt about presence, and present (1) when clearly observed. Reflex and injury scores for an individual animal are then summed and divided by the total number of measured criteria to calculate proportion impairment (QVA score); where no impairment or injury would score zero (0) and maximum impairment and injury would score one (1).

4.5.4 Applications for QVA

QVA can be used to directly assess vitality impairment for animals captured and discarded from commercial fisheries. Values for vitality impairment assessed with QVA can be calibrated for prediction of delayed mortality and used in a variety of ways in fishing industries. The calibrated QVA score can be used, as RAMP has been used, to monitor performance and adjust design of fishing gears (Hammond *et al.*, 2013), for fisheries stock assessments and management (NOAA Fisheries, 2012), and in experiments designed to determine the role of stressor factors in escapee and discard survival (Raby *et al.*, 2012).

The influence of recreational fisheries (particular angling) on marine fish stocks and ecosystems has become an increasingly important topic for fisheries management (e.g. Post *et al.*, 2002; Coleman *et al.*, 2004; Cooke and Cowx 2006; Lewin *et al.*, 2006). Catch-and-Release (C&R) angling is a common practice in many recreational fisheries (Arlinghaus *et al.*, 2007). Ferter *et al.* (2013) reviewed C&R practices in several European marine recreational fisheries, and showed that the release rates for several species were over 60% of the total catch in some European countries. Only a few studies have used or mentioned the vitality indicator approach for estimating post-release mortality in the recreational fishery context (e.g., Campbell *et al.*, 2010; Cooke *et al.*, 2013). However, the inclusion of mortality indicators in traditional C&R mortality studies has the potential to extrapolate mortality estimates to different regions and similar fisheries without the need to conduct extensive field experiments. The availability of spatio-temporal mortality estimates is important for area-based fish stock assessments and can improve future stock managements. Furthermore, vitality assessment could be useful for anglers to quickly evaluate the condition of fish and its potential survival, thus acting as a decision-support tool for anglers.

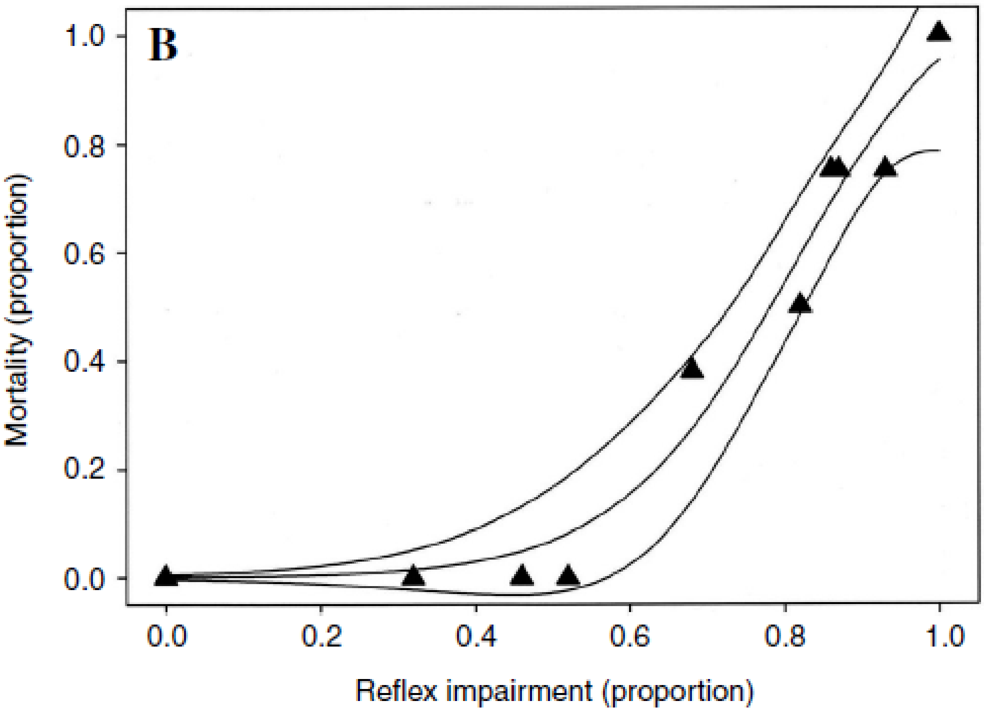


Figure 4.1 – An example relationship between reflex impairment and mortality, with confidence intervals (From Humborstad *et al.*, 2009).

4.6 Predicting Survival from Vitality Assessments

The vitality assessment methods of SQA and QVA give direct measurement of unimpaired and impaired states in animals. To calibrate vitality impairment as a tool for predicting discard survival, animals must be exposed to appropriate stressors, their impairment observed, and the likelihood of survival at each level of the vitality index observed using either captive observation (see section 5) or tagging and biotelemetry (see Section 6)(Davis and Ottmar 2006; Davis 2007). To avoid extrapolation when predicting survival, animals must be exposed to stressors that produce impairment and survival ranging from 0–100%. Models can then be constructed to show species-specific relationships between fishing conditions, impairment, and survival or mortality (e.g. Figure 4.1): "Vitality-Correlated Survival" (VCS). Once validated, vitality impairment can be used to indirectly predict species-specific discard survival from the relevant "Vitality-Correlated Survival" (VCS) relationship.

4.6.1 Calibrating Vitality-correlated Survival

The necessary steps to conduct this calibration process are detailed as follows, and summarized in Figure 4.2.

1. Choose appropriate vitality measures according to the intended use (see section 4.2):
    a. Semi-quantitative Assessment (SQA) used for rapid assessment by fishery observers under commercial conditions (section 4.3); or
    b. Quantitative Vitality Assessment(QVA) used for hypothesis testing with greater resolution of impairment (section 4.4).

2. Identify Relevant Stressors and Injuries:
    a. Use pathway analysis to identify likely stressors & injuries (see section 7);
    b. Conduct *in situ* observations to identify actual stressors & injuries; and
    c. Select most relevant stressors & injuries (see section 4.6.1).

3. Identify Consistent Reflex Responses (if using QVA):
    a. for a particular species, collect a sample of unimpaired animals (i.e. "controls", see section 8);
    b. define the reflexes, and other responses and injuries, that can be consistently tested and scored (see section 4.5.2); and
    c. Use reflexes that consistently respond to stimuli.

4. Conduct experiments to measure impairment and survival over a representative range of stressors:
    a. Design the experiments to include gradients of relevant stressor effects (section 7);
    b. Observe resulting vitality impairment and injuries over a representative range of fishery associated stressors
    c. Observe corresponding vitality related survival, using an appropriate method (section 3.6).

5. Model and validate the relationship between Vitality Impairment and Survival
    a. Correlate known levels of vitality with survival likelihood estimates using captive observation studies (see section 5) and/or tagging/biotelemetry studies (see section 6); and
    b. Use predictive models to provide estimates of discard survival (with confidence intervals) from independent measures of vitality impairment, for the same species and range of fishery associated stressors (see section 9).

4.6.2 Selection of Appropriate Stressors for Calibration

Two approaches can be used to induce a range of stress and impairment in animals caught in fisheries. The most efficient method is to make observations in real fishing operations, over a representative range of fishing conditions, pairing vitality assessment from captured fish with measurement of their survival rate. Different stressor types should also be investigated depending on the 'operational system' under study for which stress and mortality is to be modelled; i.e. recreational or commercial fishing (e.g., trawling, netting, trapping, longlining).

A second approach is to design experiments that test for effects of individual stressor types, while measuring the vitality and survival of the experimental subjects. Stressor types may be grouped as (1) physical, having an influence through exercise, pressure, temperature and water turbidity, (2) ecological, which derive from social stress, predation, and food availability, and (3) chemical sources, resulting from changes in pH, O2, CO2, and xenobiotics (Davis 2010). Stressors may be acute (short term) or chronic (long term) and their strength can range from mild to severe which can be gauged by the induced stress response and its outcomes (Barton 1997; Huntingford *et al.*, 2006). Since different stressor types (physical, ecological, chemical) may affect reflex responses in different ways, testing combinations of reflexes and injury ensures that the effects of multiple stressor types are included in the calculated impairment index.

4.6.3 Controls

The baseline controls for calibrating and validating vitality indices in each species of interest are animals with unimpaired reflex actions, without injuries, and without mortality under appropriate conditions of captive observation or tagging/biotelemetry. In difficult research situations where resources are limited, captivity or tagging may produce low levels of mortality in unimpaired control fish. This mortality indicates that holding or tagging conditions can be improved, if possible (see section 8). However calibration and validation of the relationship between vitality impairment and mortality can proceed if the investigator is willing to assume the uncertainty for interpretation introduced by control mortality (see Sections 8 and 9).

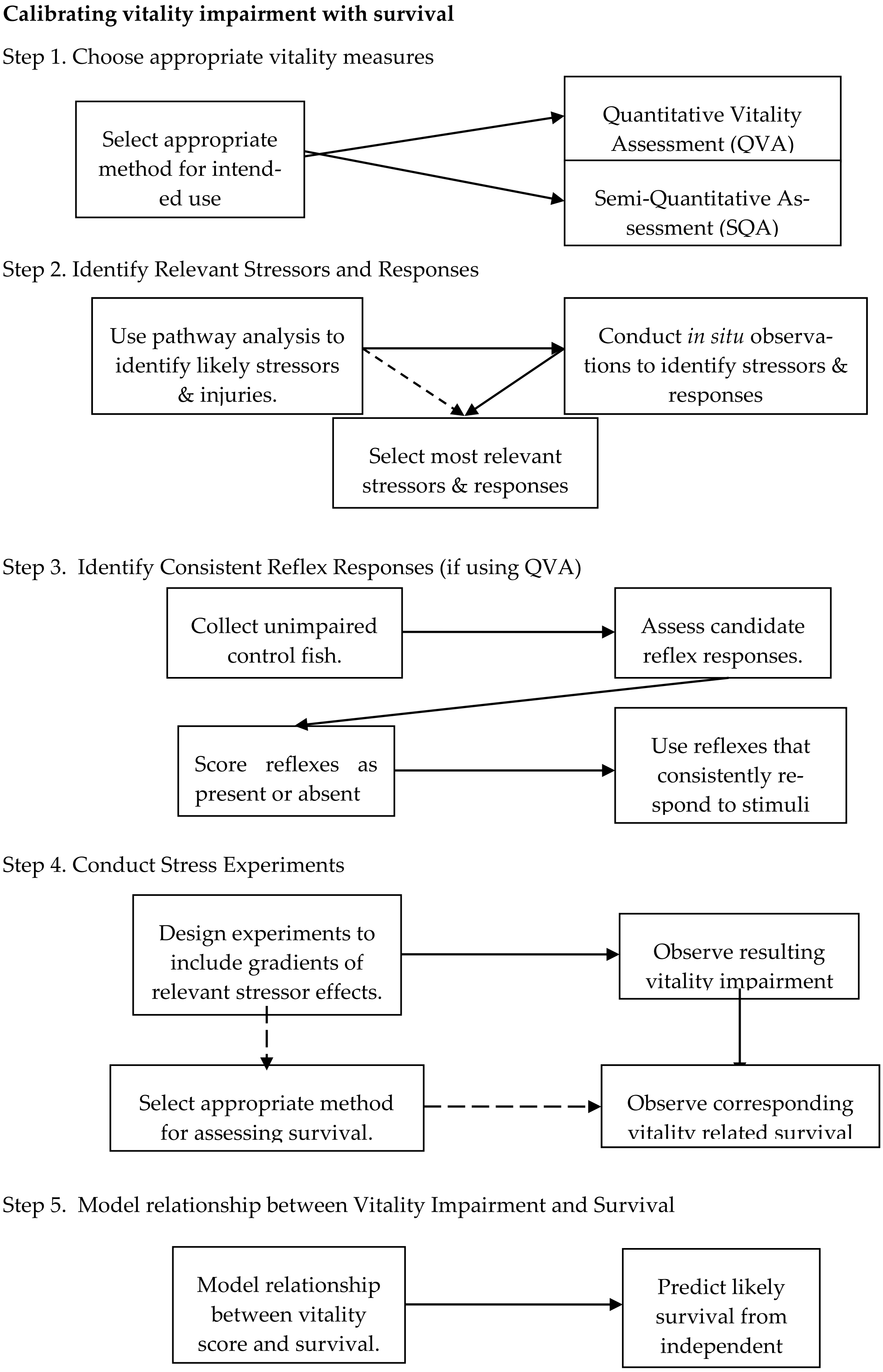


Figure 4.2 – Schematic diagram of the process for calibrating vitality with survival, adapted from Davis (2010).

4.7 Limitations and uncertainties of Vitality Assessment

4.7.1 Coarse Mortality Indicators

This method has limited resolution of vitality (e.g. time to death) and is restricted in context to the specific stressors observed in an assessment (e.g. hypoxia). As such, this method provides an approximate relative measure of vitality between species (or subgroups of) for specific stressors, but unlike SQA and QVA cannot be used to define a species-specific measure of vitality for a range of fishery associated stressors.

4.7.2 Semi-Quantitative Assessment (SQA)

Some degree of subjectivity in SQA between observers is an inherent property of this method. There will likely be differences between observers in whether a fish is ascribed to one vitality category vs. an adjacent category and even over time from one observer. On average, this may affect the precision of SQA derived observations, but generally not the accuracy. Such classification subjectivity can be reduced, but not completely eliminated, with effective training and with a clearly defined protocol. It can further be explicitly modelled during data analysis (e.g., Benoît *et al.*, 2010).

4.7.3 Quantitative Vitality Assessment (QVA)

The effective use of QVA to score vitality impairment is dependent upon the following assumptions:

1) Vitality is inversely related to reflex impairment and injury;

2) Reflex impairment and injury are directly related to stressor types and intensities;

3) Reflex impairment occurs rapidly once critical thresholds in stressors are reached;

4) Vitality correlated survival (VCS) relationship is species-specific;

5) Vitality correlated survival (VCS) relationship used for a species is experimentally derived by inclusion of representative stressors and animal sizes, ages, and sex.

6) Vitality correlated survival (VCS) relationship is stable for a species and representative conditions.

7) All reflex actions and injuries in VCS are given equal weighting.

8) Observers objectively score presence or absence of reflex action in a replicable manner.

These assumptions have been tested and validated for several species and stressor contexts, with and without scoring for injury types (e.g. Humborstad *et al.*, 2009; Davis 2010; Campbell *et al.*, 2010; Barkley and Cadrin 2012; Raby *et al.*, 2012; Stoner 2012).

The species and stressor specific nature of QVA (i.e. assumptions 4, 5 and 6) means care must be taken to ensure that vitality scores are derived from reflex impairment observed in a representative sample of animals exposed to a representative range of stressors. Failure to account properly for all the critical stressors in the discarding process could lead to confounded effects and instability in the vitality scores.

As with SQA, the precision of QVA is dependent upon how consistently the observers score the presence or absence of the reflex or injury. However, the more objective approach to scoring adopted with QVA (c.f. "rule of doubt") is likely to reduce uncertainty associated with observer bias.

4.7.4 Predicting Survival from Vitality Assessments

Vitality based predictors of survival are dependent on the observation methods used to calibrate vitality with survival. In this respect, any resulting survival estimates will be limited by the same factors inherent in estimating survival, either using captive observation, or tagging and biotelemetry. Captive observation of animals may introduce captivity related biases (e.g. method related mortality and excluding predation)(see Section 5), while tagging or biotelemetry may introduce statistical artefacts (Thorsteinsson, 2002) or sources for mortality that are not related to initial capture and discarding stressors (e.g., additional stressors, predation, disease, and food limitation)(see Section 6).

While behavioural impairment (and other indicators of stress) associated with vitality may indicate an increased likelihood of predation (e.g. Ryer, 2004; Raby *et al*, 2013) or immuno-supression (e.g. Ellis, 1981; Lupes *et al*, 2006; Wedemeyer and Wood, 1974), measures of vitality (i.e. QVA and SQA) should not be assumed to be reliable predictors of such post-release events. Such events are also dependent upon additional factors that cannot be accounted for by a vitality assessment alone, for example: proximity to potential predators and associated likely encounter probability; or prevalence of pathogens within a population and/or environment.

In addition, current evidence indicates that vitality-dependent survival estimates are largely species-specific and likely fishery-specific. Therefore, the estimates of vitality-dependent survival will only be reliable if their calibration encompasses the relevant stressors experienced by discarded fish in the fishery. Consequently, until it can be reliably demonstrated that these mortality predictors are transferable between certain species and gears, it will be necessary to have species and fishery specific vitality-survival calibrations. Furthermore, the vitality-survival calibration must include the complete range of impairment and mortality to avoid extrapolation beyond empirical evidence.

Ultimately, there is a need to validate the method of survival estimation based on vitality assessment. This is most reliably achieved by comparing the survival estimates derived using vitality observations to those obtained from a large-scale well-planned tagging project for a common fishery (see section 6)(e.g. Richards *et al.*, 1995; Trumble *et al.*, 2000; NOAA Fisheries 2014).

5 Captive Observation

Captive observation is a common technique where discarded animals are transferred into containment facilities (e.g. tanks or underwater cages), after experiencing representative fishing conditions (i.e. capture, handling and release) *in situ* or after simulation. However, the experimental subjects are not actually discarded, but are retained in captivity for a period of time to monitor their vitality and survival.

This approach facilitates monitoring of the experimental subjects, and allows both dead and surviving animals to be sampled to assess for injuries, physiological status and vitality. However, it also introduces some potential limitations with respect to the application of the survival estimates. That is, holding wild, unacclimatized animals in captivity can induce stress (Snyder, 1975; Portz *et al*, 2006), which can potentially induce captivity-related mortality in addition to the treatment effect. Controls can be used to determine whether method induced mortality has occurred (see section 8). Moreover, most examples of this technique will isolate the captive population from their natural predators, so it will not account for any predation effects on discard survival (e.g. Raby *et al.*, 2013).

5.1 Laboratory vs. Field Assessments

Captive observation can be conducted either in the field, using tanks or cages, or in the laboratory, under controlled conditions. To provide estimates of discard survival which are relevant to real fishing operations, the experimental subjects must experience conditions during capture, handling and release that are representative of fishing operations. This is best achieved using field assessments, onboard commercial fishing vessels, from where the subjects are sourced (although they may be contained either in the field or in a laboratory). Laboratory assessments, defined here as studies that do not contain an element of fieldwork, are most appropriate when researchers want to investigate the isolated effects of specific variables on discard survival.

5.1.1 Field Assessments

Captive observation field assessments can be defined as investigations that attempt to provide estimates of discard survival, where the experimental subjects are collected under realistic and representative fishing conditions (e.g. Broadhurst and Uhlmann, 2007; Depestele *et al.*, 2014; Enever *et al.*, 2008; Raby *et al.*, 2013; Revill *et al.*, 2013). The subjects are then transferred to containment facilities (e.g. tanks or cages) that are either field- or laboratory-based. Frequent reporting on this technique illustrates the feasibility and acceptable costs associated with this approach. The primary and important advantage of this technique is that the animals under study are collected from authentic fishing conditions and have therefore been exposed to realistic and combined stressors associated with the capture and discarding process. For this reason the results from studies conducted in this manner are likely to be trusted by the fishing industry.

A key consideration with captive observation is that it does not account for predation effects and so potentially overestimates discard survival levels, which must be made explicit when presenting the results (Raby *et al*, 2013). Captivity may also exclude stressors that would otherwise be experienced by discarded fish and so it is possible that subjects may survive better in the containment facilities than if released, which may also overestimate survival. However, in general, the additional stressors associated with being contained are considered to have a larger effect on subjects (Portz *et* *al*, 2006), i.e. that the method is more likely to induce mortality than to increase survival.

Captivity in tanks or cages, and transfer of organisms from the fishing operations to the holding tanks, can induce additional handling and captivity stress, and therefore requires careful use of appropriate controls. Where captivity stress is observed survival estimates observed in the treatment subjects may be an underestimate of the true value. Captive observation studies can be expensive and consequently suffer from low levels of replication. This can mean that the results may not be representative of the management unit and the statistical powers of the data are reduced. Integration with vitality assessments (section 4) and tagging/biotelemetry assessments (Section 6) can be used to substantially increase the utility of the discard estimates derived from captive observation (see section 3).

5.1.2 Laboratory Assessments

In the context of discard survival, laboratory based assessments can be used to investigate isolated variables and their effects upon the behaviour, physiology and survival of subjects under controlled conditions. Although the conditions in laboratory experiments can attempt to emulate fishing practices, representative stressors are not usually obtainable. Therefore, laboratory based experiments are not usually suitable for generating discard survival estimates *per se*.

Laboratory assessments do enable detailed studies into the mechanisms of mortality and injuries, using untreated controls as a baseline. Such studies also enable the researcher to isolate the assumed factors singularly, or in combination, and estimate their relative importance on fish vitality and the impact on survival. Laboratory assessments also offer the opportunity to undertake post-mortems and physiological investigations, and allow many replicates providing greater statistical power. With increasing focus on animal welfare, laboratory assessments allow smaller numbers of animals to be used in experiments.

As stated above, the controlled conditions of the laboratory cannot mimic commercial fishing conditions and the interaction of stressors experienced by fish. The subjects undergoing treatment may also be unrepresentative of commercially caught fish (see Section 5.2.1). Subjects kept in captivity for longer periods can become acclimatized to captivity and potentially behave differently than "wild" specimens. It is essential to keep the experimental subjects under as close-to natural conditions as possible.

5.2 Designing a captive observation assessment

The design of an effective captive observation assessment depends on four key elements:

1) obtaining a representative subject population;
2) transfer into captivity;
3) containment in appropriate conditions; and
4) monitoring.

At each stage of the study, it is important to minimize the effects of captivity on the experimental subjects. Captivity should not be detrimental to the vitality of the subjects; controls can be used to determine whether there is any method induced mortality (see section 8). This is achieved by ensuring that the holding conditions and containment facilities correspond to the subject's biological and behavioural needs as far as possible. There are useful and detailed guidelines available on keeping aquatic animals in captivity (e.g. Nickum *et al*, 2004; Portz *et al.*, 2006; Jacklin and Combes, 2007). This section only briefly reviews the most pertinent aspects.

5.2.1 A representative subject population

Based on the key influencing factors (technical, environmental, biological; see Sections 2 and 7), the experimental subjects should be exposed to suitable stressors, that are representative of normal fishing conditions, in a controlled or measurable way (see Section 7). Test subjects will usually have been caught in a standard fishing operation, handled according to normal fishing practices and, at the point at which they would be released to the water, transferred into captivity.

5.2.2 Transfer into captivity

Following treatment, the experimental subjects are transferred to a containment facility (e.g. a tank or sea cage) for monitoring. Ideally, this transfer should be representative of the conditions the discarded fish would normally experience during release. This includes both handling protocols and anticipated changes in environmental conditions between the surface and the habitat to which they would normally return (e.g. temperature, depth, and light intensity). For example, if fish are released via a chute or pipe from the side of the vessel, this could be effectively simulated by fitting the receiving sea cage to the outlet, and then sinking the filled cage to the seabed. Where this is not practical, the effects of the transfer should be controlled to minimize any associated stress and injury (e.g. minimizing air exposure).

In some instances, the transfer will involve handling individual fish, which may provide an opportunity to conduct a vitality assessment, with handling times and conditions still within normal ranges (see Section 4). However, sometimes the transfer may involve many fish at a time (e.g. when simulating the slipping of small pelagic from purse-seines; Huse and Vold, 2010; Tenningen *et al.*, 2012), in which case a vitality assessment can be conducted for a subsample of fish. At all stages of the transfer, any potential influential stressors should be monitored (see Section 7).

5.2.3 Containment facilities

The conditions in the containment facilities should ideally correspond to biological and behavioural needs of the species under investigation (e.g. Breen, 2004; Broadhurst *et al.*, 2006; Nickum *et al*, 2004; Jacklin and Combes, 2007). These needs will often be species-specific. For example: flatfish require a non-abrasive bottom surface area to rest on, as opposed to a large tank volume (Van Beek *et al.*, 1990), while pelagic schooling species require volumes sufficient to maintain normal schooling behaviour (e.g. Misund and Beltestad, 2000). Scombrids require high water flow (e.g. bluefin tuna in aquaria). *Nephrops* and other cannibalistic or aggressive species may require isolation from each other (e.g. Castro *et al.*, 2003; Wileman *et al.*, 1999).

Containment facilities can be broadly categorized into two forms:

- Tanks or ponds – where the water holding the subject population is contained by a man-made construction. The water is isolated, and therefore its quality is dependent on treatment or filtration and a flow-through or recirculation supply. As such, tank facilities enable the observer to maintain a high degree of control over the subject population. They also generally allow for the subject population to be frequently monitored. However, generally their volume can be restrictive and providing representative conditions is challenging.

- Cages – where the subject population is contained in a volume of water, generally within a larger natural water mass, using a man-made (typically netting) construction. The water quality is determined by the surrounding water mass, and depends on having sufficient exchange through the cage structure. This means that using cages in the field makes it simpler to provide representative environmental conditions. However, finding a suitable location for the cages, their isolation from the observer and large size can make effective monitoring of the subjects challenging.

The development of appropriate containment facilities will often require preliminary investigations to assess their effectiveness and these are best undertaken in association with the development of captivity (method) controls (see section 8). A pilot study, prior to the main experiment, to assess the suitability of the cages or tanks is often valuable and may prevent costly investments in unsuitable equipment.

Key characteristics to be considered when designing containment facilities include, for a given species:

- Non-injurious, non-toxic construction and materials
- Volume / surface area
- Stable and appropriate environmental conditions
- Sufficient water quality and exchange
- Water movement
- Lighting conditions; intensity, spectrum and periodicity
- Shelter
- Nutrition
- Exclusion of predators
- Facilitate monitoring with minimal disturbance.

Construction and materials - The design and materials used to construct the cage or tank (and associated handling equipment) should minimize the risk of injury and physiological distress. For example, there should be no sharp edges or abrasive materials (i.e. knotless netting is preferred over knotted). Where it is anticipated that subjects may strike tank walls, because of their own activity or movement of the vessel on which the tanks are kept, it may useful to install cushioning materials on the tank walls or use circular tanks. Care should be taken to ensure that the construction materials are non-toxic (e.g. Table 5.1).

Where subjects contact surfaces in the containment facility (e.g. flatfish), the risk of injury from contacting those surfaces should be minimized. In some cases, access to familiar substrata can be provided (e.g. sand, gravel) to minimize captive effects (e.g. Sangster *et al.*, 1996; Wileman *et al.*, 1999). Tank or cage shape is also important. For example, pelagic fish need cylindrical or circular cages for schooling. Also, elongated tanks may exacerbate water movement induced by vessel motion (see below).

Volume / surface area - An appropriate space for the experiment subjects should be provided, both with respect to individual needs and the size of the population to be accommodated (i.e. stocking density). For example, schooling, pelagic fish (e.g. herring, mackerel and tuna) are likely to require large volumes to ensure that the containment space does not confine their natural swimming behaviour or school structure. Alternatively, demersal species (e.g. plaice and sole) require adequate surface areas on which to rest. This can be achieved by providing layered shelving within the holding tank (e.g. Revill *et al.*, 2013).

Stocking density - It is unlikely that a captive observation experiment will be able to provide natural stocking densities for the experimental subjects. In most cases the stocking density is likely to be artificially high. However, it should not be so high that it is detrimental to the vitality of the subjects. The population density should not compromise the water quality within the tank or cage, in particular with respect to oxygen depletion and the accumulation of waste products (see below). The tolerance to crowding varies between species, and even within species depending upon their maturity and physical status.

There are few standard recommendations for optimal stocking densities for captive observations, as these will be dependent upon the species, their status and the characteristics of the containment facilities. However, information from aquaculture, sufficient investment in preliminary trials and developing suitable methods for controls, will inform this issue.

Stable and appropriate environmental conditions - It is important to ensure that environmental conditions in the cage or tanks (e.g. temperature and salinity) are representative of the habitat to which the subject should be released (i.e. its preferred habitat). Ideally, they should be stable, to minimize any confounding effects on the survival estimates; unless instability is a particular feature of the subjects normal habitat. Moreover, these conditions should be replicated and monitored in each cage or tank.

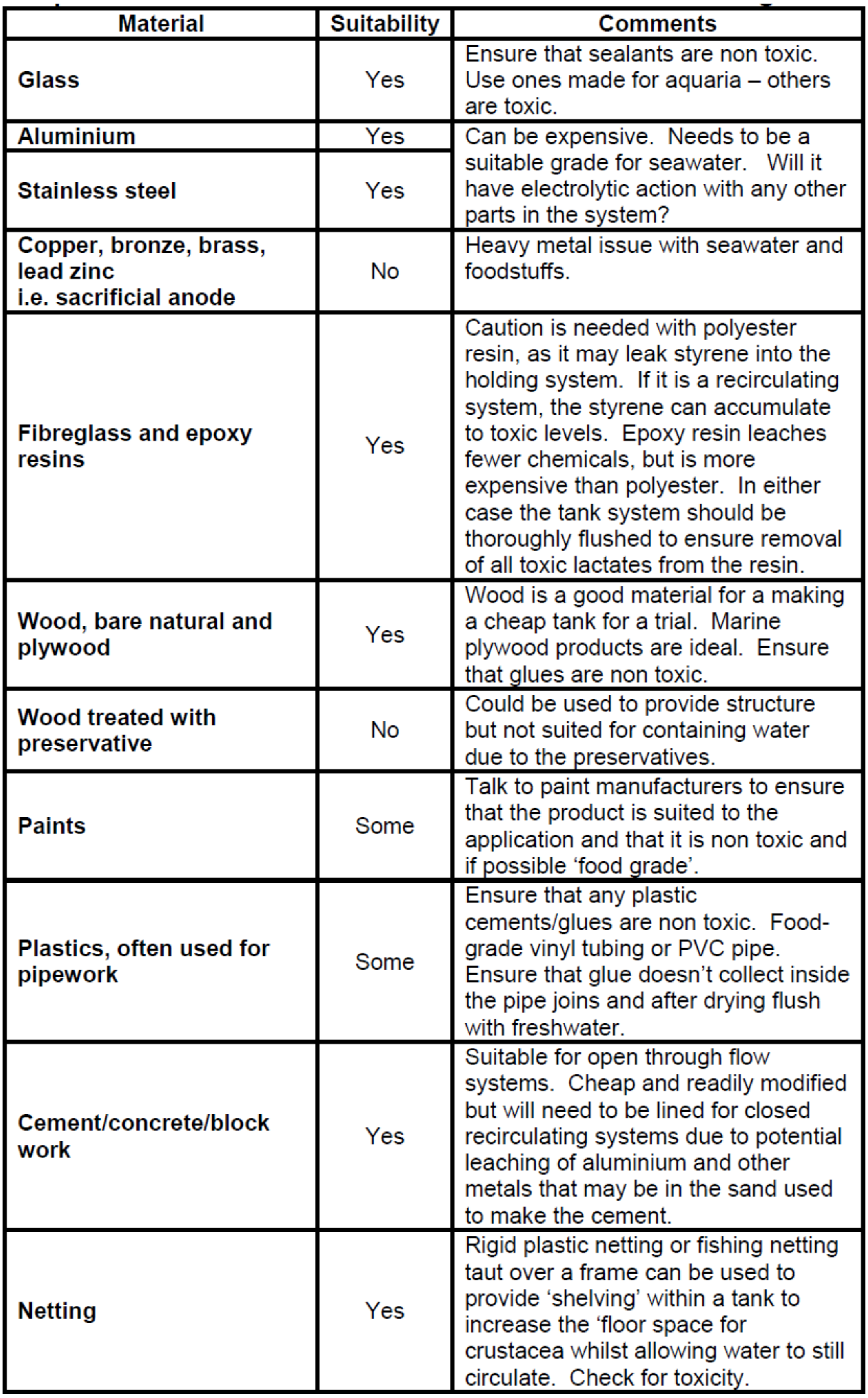
Where cages are being deployed to the receiving habitat, they should be lowered and recovered gently, ensuring that excessive water flow will not stress the animals. Simulating water pressure at depth at which the subject would return on release can be considered for tanks. Changes in key environmental parameters (e.g. depth, temperature, salinity) should be monitored throughout the period of captivity (e.g. Breen *et al.*, 2007).

Water quality / exchange - Insufficient oxygen and elevated toxins can kill the experimental subjects, but even at sublethal levels, the stress induced by these factors is likely to affect any subsequent survival. There should be sufficient water exchange within the cage or tank to ensure that oxygen levels are not depleted or that bio-waste products (particularly ammonia) accumulate. Moreover, there should be regular monitoring of concentrations of oxygen, as well as key bio-waste products, where possible.

The water exchange in tanks should be designed in such a manner, that inter-tank contamination is avoided. Ideally each tank should receive its own independent water supply. Cages may require cleaning to ensure any growth on the netting material does not compromise water exchange through the cages.

Water movement - Water movement within the containment facility can be induced naturally by tidal water currents through the cage or artificially via a water-exchange system. While some water movement is necessary to ensure water quality (see above) and promote natural swimming behaviour, excessive movement can induce additional stress. It is recommended that water flow within the containment facility is continuously recorded, particularly in cages.

Table 5.1 Properties of materials used in the construction of holding tanks for crustaceans (from Jacklin and Combes, 2007).



Material	Suitability	Comments
Glass	Yes	Ensure that sealants are non toxic. Use ones made for aquaria – others are toxic.
Aluminium	Yes	Can be expensive. Needs to be a suitable grade for seawater. Will it have electrolytic action with any other parts in the system?
Stainless steel	Yes	
Copper, bronze, brass, lead zinc i.e. sacrificial anode	No	Heavy metal issue with seawater and foodstuffs.
Fibreglass and epoxy resins	Yes	Caution is needed with polyester resin, as it may leak styrene into the holding system. If it is a recirculating system, the styrene can accumulate to toxic levels. Epoxy resin leaches fewer chemicals, but is more expensive than polyester. In either case the tank system should be thoroughly flushed to ensure removal of all toxic lactates from the resin.
Wood, bare natural and plywood	Yes	Wood is a good material for a making a cheap tank for a trial. Marine plywood products are ideal. Ensure that glues are non toxic.
Wood treated with preservative	No	Could be used to provide structure but not suited for containing water due to the preservatives.
Paints	Some	Talk to paint manufacturers to ensure that the product is suited to the application and that it is non toxic and if possible 'food grade'.
Plastics, often used for pipework	Some	Ensure that any plastic cements/glues are non toxic. Food-grade vinyl tubing or PVC pipe. Ensure that glue doesn't collect inside the pipe joins and after drying flush with freshwater.
Cement/concrete/block work	Yes	Suitable for open through flow systems. Cheap and readily modified but will need to be lined for closed recirculating systems due to potential leaching of aluminium and other metals that may be in the sand used to make the cement.
Netting	Yes	Rigid plastic netting or fishing netting taut over a frame can be used to provide 'shelving' within a tank to increase the 'floor space for crustacea whilst allowing water to still circulate. Check for toxicity.

Stress can be induced by the movement of the vessel on which tanks are installed. This can be partly relieved by tank design, such as sealed tanks with no airspaces , or small round tanks and/or the use of baffles to restrict water movement. Also the tanks should be securely fastened in a position on the vessel where the ship's motion is minimal.

When using cages, sites should be selected that are sheltered from significant tidal currents, as well as the prevailing weather. Floating cages drifting with water currents, as opposed to being anchored, can be considered (Huse and Vold, 2010). Cages should be deployed and recovered gently, ensuring that any induced water flow does not stress the subjects.

Lighting conditions: intensity, spectrum and periodicity - Many aquatic species are adapted to light intensities much lower than will be experienced at the surface (Johnson, 2012). Moreover, the subject's natural light will have a periodicity and spectrum that will be specific to its natural habitat (Johnson, 2012). To minimize captivity stress, the holding conditions should attempt to simulate natural illumination levels and patterns. If held in tanks, artificial lighting can be used with appropriately coloured or opaque construction materials to replicate natural lighting conditions.

Shelter - Some species naturally seek and require shelter, without which they are likely to become stressed (e.g. *Nephrops*). The provision of a suitable artificial shelter can alleviate this problem (e.g. Wileman *et al*., 1999).

Nutrition - Most adult aquatic species can survive several weeks without food, especially at lower temperatures. However, when observing the experimental subjects for a prolonged period, it may be necessary to provide food to meet the subject's nutritional requirements. A review of the life history of each species will provide information to determine feeding requirements. Providing food may also alleviate predation and cannibalism within the captive population. The feeding status of a fish can be a useful measure of the subject's vitality and stress status (e.g. Breen, 2004). Feeding will increase the subjects' oxygen requirements and the production of biowaste products, therefore, water quality will need to be maintained accordingly.

Exclusion of predators - Where there are likely to be intra- or interspecific interactions (e.g. cannibalism, competition and predation), it may be necessary to exclude some species or larger individuals, or have segregated facilities. Cages deployed in the subjects' natural habitat can attract predators and scavengers (e.g. seabirds, star fish, crabs and sea-lice) that can stress the subjects and enter the cage and attack live subjects or scavenge on dead specimens. Efforts should be made to exclude these animals (e.g. floating cages should be covered by netting or a lid to avoid predation by seabirds.) Also, regular monitoring (e.g. using divers) can be used to limit the attraction of scavengers by removing carrion.

Facilitate monitoring with minimal disturbance - Monitoring of the subjects should be conducted in a way that minimizes stress on the subjects. Remote monitoring technologies (e.g. video cameras) can be used to monitor mortality and vitality, without adding to captivity stress by disturbing them (e.g. Ingolfsson *et al.,* 2007). Closed tank facilities enable assessments of the physiological status of the subjects (e.g. measuring excreted levels of cortisol).

Figure 5.1 Tank arrangement used in the UK (source: Precision Pipework Ltd., Lowestoft UK).

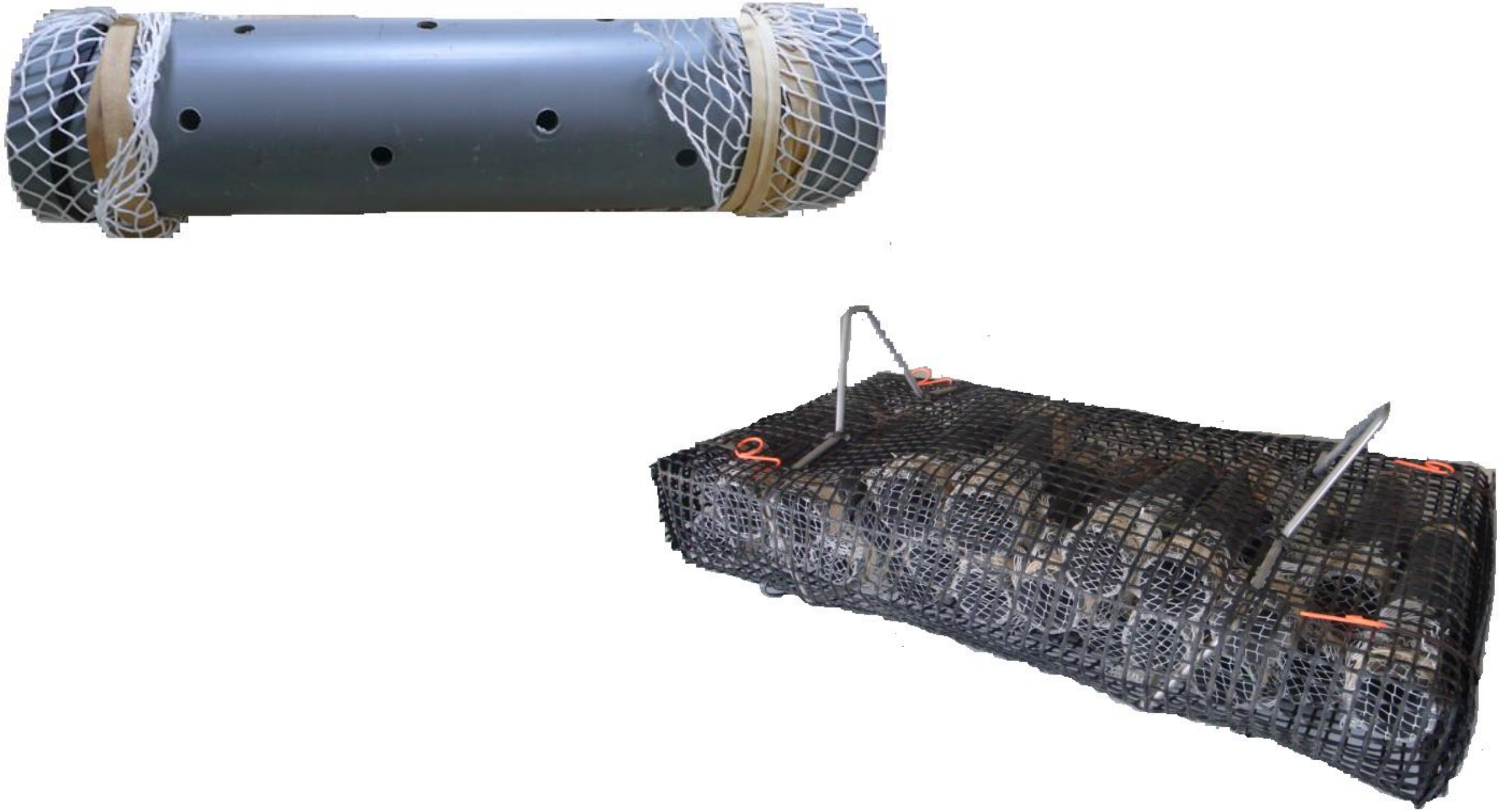


Figure 5.2 Cages used for studying *Nephrops* survival (Mehault, 2011).

Figure 5.3 Cages and holding tanks used in Dutch experiments (van Marlen *et al.*, 2013).

Figure 5.4. Cage used in German experiments in the Baltic (Weltersbach, 2013)

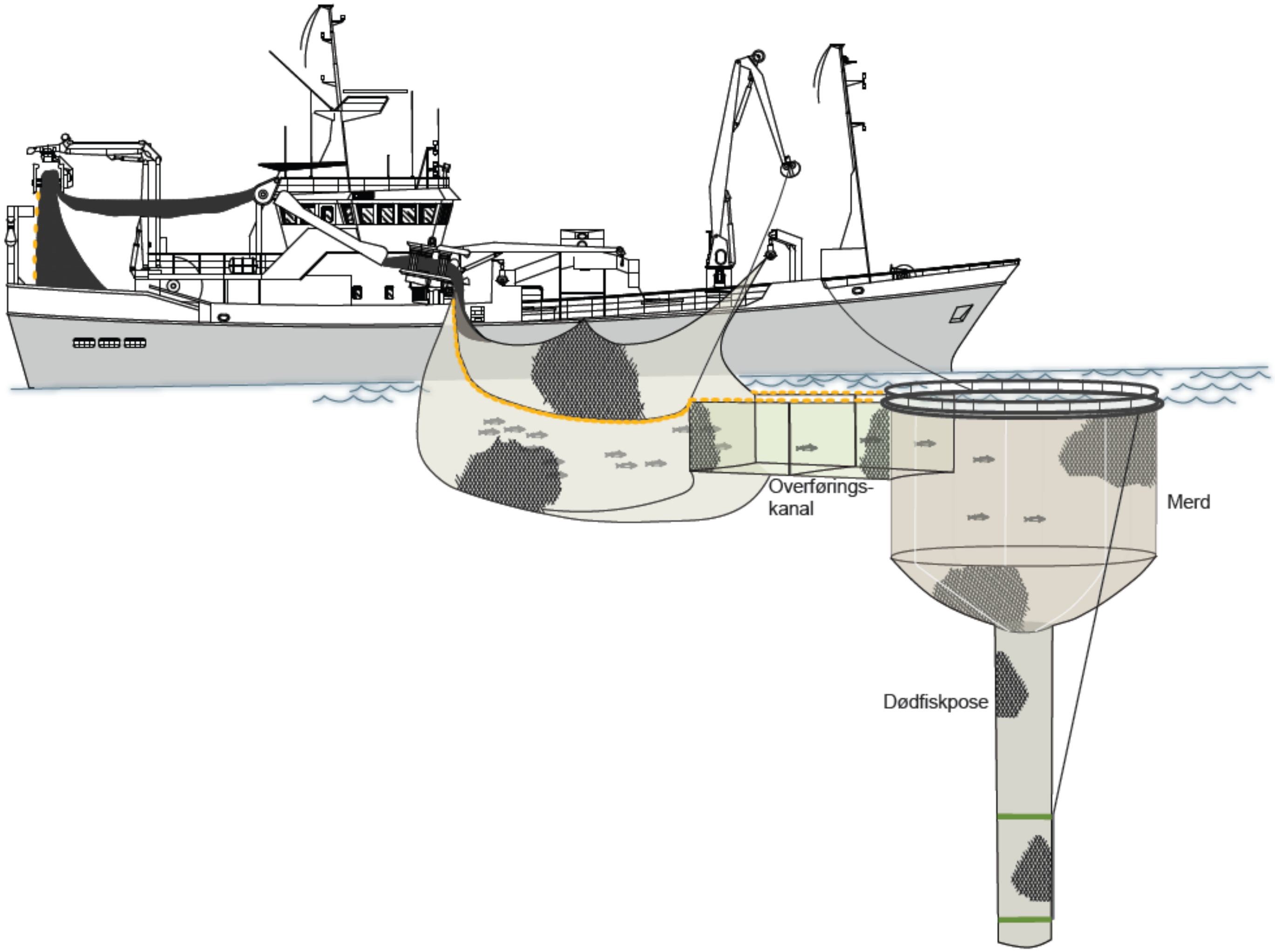


Figure 5.5 Cage set-up used in Norwegian purse-seine survival studies (Huse and Vold, 2010).

5.2.4 Monitoring

Mortality – Characterizing a subject as dead can be subjective, so a consistent protocol is necessary (e.g. Benoît *et al.,* 2013; see Section 4). Clearly defined, measurable and validated characteristics of a "dead" subject should be established prior to the commencement of the survival experiments (e.g. lack of respiratory or gill response and swimming activity, onset of rigor mortis, lack of reflexes or response to stimuli, colour of gills).

Dead specimens – At predefined times for observation, subjects that are characterized as dead should be removed as quickly as possible to reduce the risk of disease and/or the attraction of predators, and scavengers. In tanks, these can typically be removed with properly designed landing nets (i.e. those used by aquarists or by anglers). Additional stress to the remaining living subjects should be minimized. When storing fish in cages, various solutions designed for removing dead fish in aquaculture are available (e.g. Sangster, 1991; Piggott, 2013). In underwater cages, divers or ROVs may be deployed.

Observations – The observation of the captive subjects should be a compromise between obtaining accurate data on the occurrence of death, with timely removal of dead specimens, and the disturbance and stress caused by the observation. Monitoring should be done with minimal disturbance (see above).

Monitoring at regular standard intervals is required to generate a cumulative mortality profile; ideally monitoring should continue until mortalities cease and the cumulative mortality profile reaches a plateau. Mortality rates may stabilize only to increase after a lag period. Mortalities closer to the time of discarding are likely due to the capture-and-discarding process; whereas mortalities towards the end of monitoring might be due to the containment. Controls should be used to establish any method induced mortality (section 8).

Monitoring should ideally be for as long as it takes to explicitly observe the treatment induced mortality. A typical cumulative mortality curve has an asymptotic shape (Benoit *et al.*, 2013), and the experiments should continue until the mortality approaches the asymptote. This may take days or weeks depending on the species and treatment. However, in practice, the duration of monitoring often has to be a trade-off between ideal scientific needs, the available resources (sea time, budgets, available tank time) and occurrence of confounding mortality not associated with initial treatments.

In some cases bi-modal mortality may occur, e.g. in herring (pers. comm., Aud Vold and Rolf Erik Olsen). In such cases, untreated controls are needed to evaluate if a second peak of mortality is caused by the initial treatment or whether it is attributable to a captivity effect. There may be species for which the mortality rate does not stabilize. In such cases it is difficult to interpret if the mortality is related to the treatment or the captivity (section 8).

In previous captive survival assessments, monitoring has typically been done every 24 hours; this has provided a balance between the level of disturbance, resource requirements and data generation. It is recommended that more frequent monitoring is conducted in first 24 or 48 hours after discarding, during the period when highest mortality rates are often seen. In some experiments, where daily sampling of mortalities is logistically difficult or even impossible, only endpoint mortality can be monitored (e.g. Ingolfsson *et al.*, 2007; Huse and Vold, 2010).

Variables to be measured– The type of measurement will depend on the study, and the ability to sample specimens during the assessment. Length, weight and sexual maturation are important to understand the susceptibility to mortality of the population. External injuries may also be recorded, keeping in mind that handling of the fish and post-mortem processes may cause damage. Details on methods to visually assess the vitality of fish are given in section 4. Laboratory studies can utilize a much wider range of analytical techniques (for example, stress axis components (cortisol, plasma ions, catecholamines, and glucose) and hypoxia indicators (lactate) can be analysed). In tank studies, non-invasive techniques like water cortisol and ammonia are well suited. Measurements of water quality variables like oxygen content, ammonia, salinity, temperature, and current velocity are useful to establish how well the containment reflects the natural environment and to correlate changes in conditions with mortality rates.

6 Tagging and Biotelemetry

This Section will be completed following next WKMEDS meeting in Q4 2014

Mark-and-recapture studies

A traditional method to study the long-term mortality of discarded/released fish is through mark-and-recapture studies, which have been widely used in recreational and commercial fisheries to assess the migration, growth and survival rates of fish. Fish are individually tagged with different external tags (e.g. t-bar anchor tags) after being caught and then released back into their natural habitats (ICES, 1965; Parker *et al.*, 1990). Again, ideally both a control and treatment fish would be tagged and released. By using recapture data from the fishery, low-resolution information of migration, growth and survival after the release event can be collected (Pollock and Pine, 2007). Advantages of mark-and-recapture studies are: easy application, relative low costs, the possibility to have large sample sizes, and the provision of long-term mortality data under natural environmental conditions. However, mark-and-recapture studies provide only very low resolution data compared to biotelemetry studies. A problem is the uncertainty in the calculation of the catch-and-release survival rate estimates due to underreporting of recaptures and natural mortality. Consequently, to achieve a sufficient number of tag returns, a large quantity of fish has to be tagged (Pollock and Pine, 2007; Donaldson *et al.*, 2008).

Biotelemetry studies

One approach to enhance data resolution and quality of catch-and-release studies is the combination of containment or mark-and-recapture experiments with a biotelemetry study (Bacheler *et al.* 2009; Donaldson *et al*. 2008; Pollock *et al.*, 2004; Roberts *et al.* 2011). Biotelemetry studies are used to investigate short- and long-term mortality and can provide insights into (sub-) lethal effects of catch-and-release by describing behaviour, condition and fate of released fish (Donaldson *et al.*, 2008). For telemetry studies, fish are tagged with either acoustic/radio tags or satellite pop-up tags and released into their natural habitats. An acoustic tag sends all available information (e.g. fish location and physical parameters) to a nearby receiver station after being implanted into the fish. At least one close-by receiver station is always necessary to receive data. In contrast a satellite pop-up tag is attached externally, and does not need a direct contact with a receiver station. Instead it pops up after a predefined period of time and sends its stored data via satellite link after reaching the surface (Block, 2005; Donaldson *et al.*, 2008).

A great advantage of telemetry studies is the provision of high-resolution data of migration patterns, predator avoidance, behaviour and survival for a long time period after the release event. Thus, biotelemetry allows estimating the catch-and-release survival rates under natural conditions, including ecosystem interactions and indirect mortality due to intra- and interspecific competition. Besides, biotelemetry offers the collection of physiological, behavioural, energetic and environmental data (Donaldson *et al.*, 2008).

Disadvantages are the negative effects and potential mortality caused by the invasive tagging method for internal tags. It can be difficult to separate the effects of tagging from the impact of the catch-and-release event (Bettoli and Osborne, 1998; Donaldson *et al.*, 2008). Additionally, the implantation procedure is complicated and time-consuming (3-10 min), and requires well-trained staff. In many cases fish have to be anaesthetized which may lead to additional stress and mortality (Donaldson *et al*., 2008). Due to relatively large tag sizes, this method is not always suitable for small species or individuals. Furthermore, telemetry studies are very costly due to the high prices of the telemetric tags (ca. 500 EUR per acoustic tag and ca. 3000 EUR per satellite pop-up tag), which in most cases leads to relatively small sample sizes (Pollock and Pine, 2007).

7 Explanatory variables

The fish capture processes can disturb, stress and damage an organism which can result in its mortality. Thereby, any mortality of discards may be influenced by a range of biological (e.g. species, physiology, size, and catch composition), technical (e.g. gear design, deployment duration and speed) and environmental (e.g. temperature, hypoxia, sea state and availability of light) stressor factors (Figure 7.1; Davis, 2002, Broadhurst *et al.*, 2006; Broadhurst and Uhlmann, 2013). In other words, these factors determine conditions during fishing and influence/affect the stress, injury and possibly survival of captured-and-discarded individuals (Davis, 2002). Mortality associated with capture can occur prior to the point of discarding (immediate discard mortality) (Braccini *et al.*, 2012), or after the point at which the subject is discarded (delayed discard mortality).

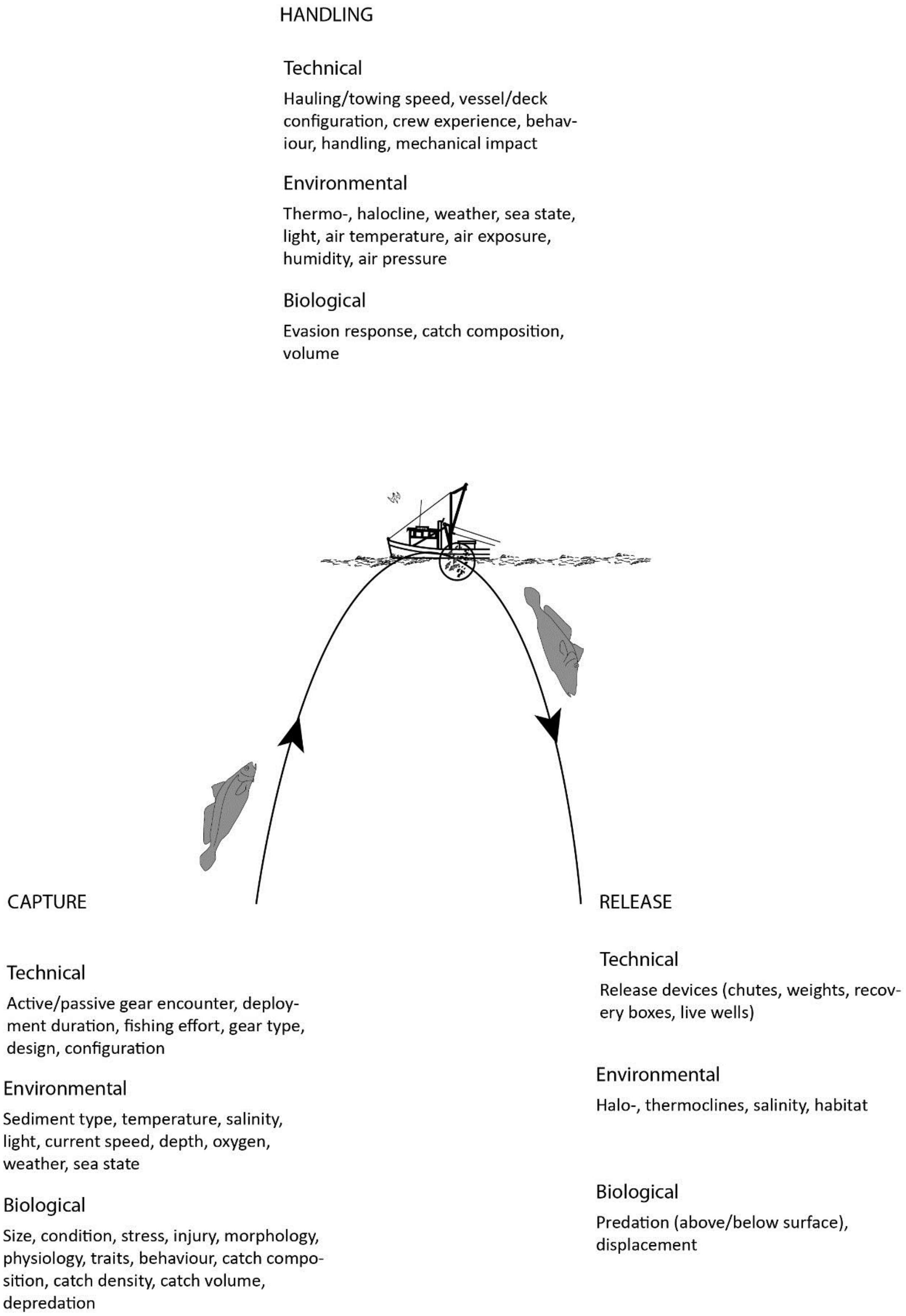
When designing experiments to estimate discard survival, it is important to measure the main factors influencing the stress, injury and ultimately survival of discards, to attribute sources of variability. By conceptually tracing an organism's pathway of being i) captured, ii) handled above the water surface, and iii) released back overboard and eventually returning to its habitat, some of the relevant technical, environmental and biological variables can be identified (Figure 7.1). The ability of an organism to survive the capture and discard pathway will be dependent on its innate capability to tolerate changes in conditions (Davis, 2002; Broadhurst *et al.*, 2006). While individuals may be able to tolerate certain changes, they may be 'pushed over the edge' through a combination of stressors.

The following section provides a brief overview of these factors by i) conceptually conceiving key factors potentially affecting a captured-and-discarded animal and ii) by reviewing primary literature of experiments that have demonstrated predominant effects.

7.1 Stressor

A stressor can be defined as a factor which induces a stress response. Isolating a single stressor variable is difficult, particularly in field environments, due to the need to control for effects of all other variables. Laboratory experiments may be useful to for this aim (section 5) (Kennelly *et al.* 1990; Uhlmann *et al.* 2009).

There is an array of different stressors experienced by a discarded fish and these will compound with each other. The compounded effects can lead to the mortality of the subject, but the way in which they interact may not be simply additive or multiplicative but synergistic or antagonistic. Unravelling the precise individual and combined influences of multiple stressors is challenging, but so long as survival estimates are based on a range of stressors that reflect the fishery, then they can be considered representative. So monitoring the different stressors is essential to determine the representativeness of the discard survival estimates, but they can also be used to inform on potential mitigation measures that may increase survival. The first step in a framework to assess and potentially mitigate discard mortality is to describe in detail the ranges of technical, environmental and biological conditions and characteristics pertinent to a particular fishery and the discarded species of interest.



HANDLING

Technical

Hauling/towing speed, vessel/deck configuration, crew experience, behaviour, handling, mechanical impact

Environmental

Thermo-, halocline, weather, sea state, light, air temperature, air exposure, humidity, air pressure

Biological

Evasion response, catch composition, volume

CAPTURE

Technical

Active/passive gear encounter, deployment duration, fishing effort, gear type, design, configuration

Environmental

Sediment type, temperature, salinity, light, current speed, depth, oxygen, weather, sea state

Biological

Size, condition, stress, injury, morphology, physiology, traits, behaviour, catch composition, catch density, catch volume, depredation

RELEASE

Technical

Release devices (chutes, weights, recovery boxes, live wells)

Environmental

Halo-, thermoclines, salinity, habitat

Biological

Predation (above/below surface), displacement

Figure 7.1. Stressors influencing captured-and-discarded organisms during fishing resulting in either synergistic, antagonistic or cumulative stress responses (reproduced with permission from Davis, 2002).

7.2 Literature review identifying key explanatory variables

A literature review was undertaken which identified all explanatory variables that have been linked with a measurable stress, injury or mortality of discarded animals. The outputs are categorized by conventional gear types i) trawls and dredges; ii) gillnets and traps; iii) hook and line; iv) longlines and jigging or v) pelagic seines and trawls. For each of these gear groups, available key literature (reviews, if available) of both marine and freshwater fisheries was scanned for cases where a stressor effect was demonstrated or not detected. The number of primary literature studies for each demonstrable effect, indicated the potential relevance of such a factor across or within gear groups (Table 7.1). For trawls and dredges, existing reviews by Broadhurst *et al.*, (2006), Revill *et al.*, (2013), and Suuronen and Erickson (2010) were used. For gillnets and traps the recent review by Uhlmann and Broadhurst (2013) was used.

The factors which have been studied for hook and line angling gear are based on two relatively recent reviews that covered both freshwater and marine fisheries, i.e. Bartholomew and Bohnsack (2005, pages 134–136) and Arlinghaus *et al.* (2007, pages 115–125); thus excluding studies published after 2007. The factors which have been studied for long lines and jigging machines are based on an online database search. For pelagic seines and trawls no review existed, therefore, available primary literature studies, mainly on purse-seines, were scanned for relevant factors (Hall and Roman, 2013; Huse and Vold, 2010; Tenningen *et al.*, 2012; Olsen *et al.*, 2012, Marçalo *et al.*, 2008; 2010; 2013).

7.3 Selection of variables

The review of primary literature studies identified that among technical and environmental factors, gear configuration, handling, deployment duration, water temperature and air exposure were the most studied, and frequently associated with discard survival (Table 7.1). Body size was also very important (Table 7.1). For active gears, increasing deployment duration, air exposure and air temperature reduced survival of many species (Table 7.1). Among passive gears, gear materials, gear configuration (i.e. use of selective devices), together with an organism’s physical injury were relevant in explaining variation among discard mortality.

Several factors were rarely associated with discard mortality, such as sediment type and salinity (Table 7.1). This was either because they were measured but not relevant, or because they were rarely mentioned. For the latter, this may also apply to factors such as predation, catch composition and behaviour.

Table 7.1. Count of primary literature (N= number of reviewed studies per gear type) that demonstrated significant effects of technical, environmental, and biological factors during demersal trawling and dredging, gillnetting and trapping, hook and line fishing, longlining and jigging, and pelagic purse seining associated with discard mortality. The factors are sorted by relevance in descending order. --, not available; ns, not significant.

	Demersal trawls and dredges (N^1=60)	**Gillnets and traps (N^2=85)**	**Hook and lines (N^3=XX)**	**Longlines and Jigging (N^4=XX)**	**Purse-seines (N^5=6)**	**Count**	**ns**
Gear configuration	1	40	29	20	--	69	21
Handling	8	8	29	6	--	45	6
Deployment duration	17	8	13	9	--	36	11
Body size	10	10	15	12	2	35	14
Water temperature	11	4	22	7	1	35	10
Air exposure	23	5	12	--	--	34	6
Injury	8	9	13	--	3	30	3
Depth	1	6	9	4	--	17	3
Air temperature	14	1	--	1	--	15	1
Gear operation	--	1	6	--	7	13	1
Gear type	--	5	12	--	--	11	6
Physical condition	2	2	3	--	4	10	1
Season	4	3	3	1	--	9	2
Catch volume	8	--	--	--	1	8	1
Depredation	--	10	--	--	--	8	2
Predation	4	--	1	--	1	6	0
Sex	4	1	--	2	1	4	4
Behaviour	1	2	--	--	--	3	0
Dissolved oxygen	--	1	2	--	--	3	0
Light	2	1	--	--	1	3	1
Catch composition	--	1	--	--	1	2	0

Infection	--	2	--	--	--	2	0
Location	--	1	--	1	--	2	0
Catch density	--	1	--	--	--	1	0
Recapture	--	--	1	--	--	1	0
Salinity	1	--	--	--	--	1	0
Sediment type	1	--	--	--	--	1	0
Species	--	1	--	--	--	1	0
Stress	1	1	--	--	--	1	1
Weather	--	--	1	1	--	1	1
Year	--	1	--	--	--	1	0

[1] Broadhurst *et al*., (2006); Revill *et al*., (2013); Suuronen and Erickson (2010)

[2] Uhlmann and Broadhurst, (2013)

[3] Arlinghaus *et al*., 2007 (pp. 115-125); Bartholomew and Bohnsack, 2005 (pp. 134-136)

[4] Web of Science search

[5] Hall and Roman, (2013); Marçalo *et al*., 2008, 2010, 2013; Huse and Vold, (2010); Tenningen *et al*., (2012); Olsen *et al*., (2012)

7.4 Measurement of variables

The majority of the factors listed in Table 7.1 and Appendix IV can be measured by simple means via observations, time recording, or electronic data logging of (e.g. water quality such as temperature, dissolved oxygen, salinity, as well as light levels). Different configurations of gear and fishing practices often require specific methods. For example, deployment duration may be measured as the time period between (i) winch starts (e.g. trawlers), (ii) complete submergence of the gear underwater (e.g. gillnets or traps), or (iii) during bottom contact (trawls, traps or gillnets). Load cells can be used to measure pulling force on trawl wires (drag force, Broadhurst *et al.*, 2013) and acoustic transmitters and receivers for trawl shape and catch size. Remote monitoring may also require specific technologies to measure and document factor interactions (Bryan *et al.*, 2014; Mallet *et al.*, 2014). Emerging technologies to remotely monitor fishing operations may provide effective means to record data automatically (Mangi *et al.*, 2013).

The measurement of relevant factors is not limited to natural conditions. Study organisms may also be stressed from research-related handling (e.g. measurement, tagging, or holding in captivity). Thus, animal sensitivities towards stressors found in their natural environment may also extend to artificial conditions. For example, the conditions under which subjects are contained will be important to measure for species sensitive to changes in light.

To identify which factors may be relevant to measure, it will be necessary to look at the sensitivities of the study species, the path that it travels and stressors it is experiencing during a given capture-and-release process (Figure 7.1), and the experimental method that was chosen to assess discard mortality. While the *a priori* choice of potential and quantifiable explanatory factors may benefit from an organism's 'path analysis' (Figure 7.1), the drafting of data recording sheets (Appendix V) may also assist the process of "thinking through" all relevant stages of data collection, its replicability and feasibility under experimental conditions.

The majority of studies that were reviewed here were done in an applied fisheries context and illustrated that gear configuration can have a significant effect on the fate of discards (Table 7.1; Appendix IV). However, in several cases no significant effects were found (Table 7.1). Due to a potential publication bias and different emphasis of the considered reviews (e.g. mitigation, gear selectivity), comparisons of why certain factors seemed more relevant to one gear type than another, were not done. After a selection has been made of factors to be measured, it may be necessary to prioritize among them how these shall be measured depending on a desirable level of accuracy with minimal measurement error. For example, measuring the time of air exposure for individual fish accurately with a stop watch may provide better data than roughly estimating air exposure (as the time period between start and end of sorting); whereas the accuracy gained from measuring catch volumes using expensive scales may not contribute much in explaining variability of mortality.

A more detailed description of the key factors, their effects and how some of these can be measured is given in the following section and in Appendix IV. Thereby, factors are discussed in the order of their association with an organism during the three different phases of: capture, handling on board and release (Figure 7.1). Not all factors are pertinent to all fisheries, some may be more important than others for a particular gear type. Wherever this was the case, it was highlighted. For example, towing speed does not apply to passive gillnet fisheries. Or crowding and herding are phenomena pertinent to seines and trawls.

Although factors have been classified as above in Table 7.1, potential intercorrelations may exist between them. For example, the way catches are handled on board may also determine the time period of air exposure. A similar correlative relationship between factors exists where a given environmental or technical factor provokes a measurable response from the organism. For example, among species with swimbladders, depth determines the occurrence and severity of the various known barotrauma injuries. In pelagic purse-seines, depleted dissolved oxygen concentrations during crowding and herding may trigger an evasion response which causes fatigue. Hence, there is a potential to measure either the cause or the effect.

7.5 Conceptually identifying key variables

Conceptually conceiving factors that could potential affect the survival of a captured-and-discarded animal is a useful method to identify key stressors. By tracing an organism's pathway of being i) captured, ii) handled above the water surface, and iii) released back overboard and eventually returning to its habitat, relevant technical, environmental and biological variables can be identified.

7.5.1 Capture phase

Technical stressors

The **configuration of the fishing gear** plays an important role in how animals are caught and interact with gear, with what components they come into contact and what the intensity of this contact is.

In trawl fisheries, the interaction starts with a stimulus by the gear such as otter boards and sweeps (Wardle, 1993), tickler chains (Van Beek *et al.*, 1990; Kaiser and Spencer, 1995), and groundgear (for trawls) which can cause physical contact and possible injury (Chapman, 1981). Next, the animals pass through the gear towards the codend. During that process, further physical contact can occur, resulting injuries such as abrasion. The characteristics of the netting material (i.e. stiffness, yarn surface, knot thickness, mesh shape;) are important in that process (Millner *et al.*, 1993; Evans *et al.*, 1994). Physical barriers in the net, such as guiding panels can inflict additional injury (Lundin et al. 2012). In hook and line fisheries, the design of the hook has an effect on survival (Grixti *et al.*, 2007; Cooke and Suski, 2005) and the type of lure can be important (Arlinghaus *et al.*, 2008; Appendix IV). In static net fisheries the design of net is important, for example, fish are more likely to get entangled in trammelnets than in single layered gillnets (Uhlmann and Broadhurst, 2013).

A negative relationship typically exists between **deployment duration** and survival. The longer gears are deployed, the longer animals are exposed to the capture process, whereby crushing and injury may confound exhaustion effects. For example, both Wassenberg *et al.* (2001) and Uhlmann and Broadhurst (2007) showed that in penaeid prawn trawls, survival probabilities for discarded organisms decreased with longer tow duration (Appendix IV). In trap fisheries, discard species may be trapped and are not able to feed or move as needed (Barber and Cobb, 2007). For hook and line fisheries, longer fighting times have been shown to increase the occurrence of sublethal effects and post-release mortalities (Tomasso *et al.*, 1996; Meka and McCormick, 2005).

Towing speed is another technical factor which is shown to influence discard mortality, although not identified by any of the reviewed studies (Table 7.1). Higher towing speeds can lead to exhaustion and increased risk of injury, due to increased likelihood and intensity of contact with the gear and other parts of the catch. The movement of the fishing gear, as determined by its deigns, the nature of the seabed, depth range (Milliken *et al.,* 2009; Benoît *et al.,* 2013) and currents, can affect the type and likelihood of injuries to organisms.

The process of **hauling of fishing gear** on board, the movement of parts of the fishing gear containing the catch, physical interactions with hard parts of the vessel (which can be exacerbated by poor weather conditions), the size and composition of the catch, and the time before emptying the catch affect animal vitality in the catch. The **speed of hauling** will also affect how quickly gases in the animal's body expand, and how it can cope with this physical change (see **baro-trauma** below).

Environmental stressors

The effects of **temperature changes** (from ambient temperature at deeper depth to surface/air temperature) are well known for some freshwater and marine fish, where physiological stress and changes in behaviour have been observed (Brett, 1970; Fry, 1971; Schreck *et al.*, 1997; Davis *et al.,* 2001). A series of experiments on marine fish (Barton and Iwama, 1991; Muoneke and Childress, 1994; Ross and Hokenson, 1997) demonstrated species-specific differences in mortality associated with temperature change. Swimming performance and the ability of fish to maintain position in the net can be influenced by temperature change (Beamish, 1966; Breen et al, 2004; He and Wardle, 1988; Winger *et al.,* 1999) and thus the likelihood of physical injury, through contact with the gear or the catch.

Over a longer time-scale, temperature changes may contribute to observed seasonal effects, although few studies have taken **seasonality** into account. Other more crucial parameters may be 'masked' by this variable, but strongly correlated to it, such as ambient temperature and spawning. Cicia et al. (2010) demonstrated significant seasonal differences in the mortality rates of skates captured between February and July, mostly associated with variations in surface temperature. Revill *et al.* (2013) found differences in the survival of plaice in different seasons. Mediterranean swordfish also demonstrated lower vitality during the post-spawning season compared to prespawning, a finding attributed to the poor health condition of the spawners (De Metrio *et al.*, 2001; Damalas and Megalofonou, 2009).

With increasing depth, natural **light** levels are reduced through attenuation, which can also influence the behaviour during the capture process (Johnson, 2012). Observations and measurements of fish behaviour under conditions of low light and darkness have been carried out both in the field and in the laboratory (Batty, 1983; Olla and Davis, 1990; Ryer and Olla, 1998; Olla *et al.,* 2000), confirming that effects of light are species-specific. In some trawl fisheries, certain fish species under low light conditions, swam less, passed along the trawl faster, and did not orient themselves to the long axis of the trawl resulting in more injury and mortality. At very low light intensities, fish do not detect an approaching net (Wardle, 1993). At the other extreme, bright surface light may cause disorientation and bleaching of sensory pigments in the eye, reducing the animals' ability to make avoidance responses if released at sea

(Pascoe, 1990). For some species, short-term or permanent blindness may also occur (Frank and Widder, 1994).

Differences in **salinit**y result in varying osmotic pressures, which requires aquatic species to regulate their body water. Marine stenohaline species (e.g. *Nephrops norvegicus)* may suffer haemodilution and rapid mass gain, even after a brief exposure to non-preferred salinity ranges (Harris and Ulmestrand, 2004). Another relevant environmental factor during the capture phase is **water depth** (Table 7.1). The negative effect of a change in depth on fish vitality is mainly due to the rapid decrease of hydrostatic pressure (see Biological stressors section below).

Biological stressors

Significant variation in discard mortalities has been documented not only between studies but also within studies for some **species** (Frick *et al*. 2010; Revill, 2012). In general, sedentary species and those lacking a swimbladder (e.g. flatfish, sharks and rays) have a higher likelihood of survival (Benoît *et al.,* 2013). Several crustacean species (crabs, lobsters) and bivalve molluscs (scallops) are relatively robust and are likely to survive when discarded (Mesnil, 1996).

Fish that are captured, brought to the surface and discarded encounter depressurization (**barotrauma**; Stewart 2008), which can cause mortality (Campbell et al., 2010; Hochhalter and Reed, 2011; Nichol and Chilton, 2006; Rudershausen *et al.,* 2014). The presence and type of a swimbladder is an important biological determinant of survival (Benoît *et al.,* 2013; Rudershausen *et al.,* 2014). The most frequently observed barotrauma symptom in fish is an overinflated or ruptured swimbladder, with associated gas release into the body cavity. However, swimbladder healing after a short period of time has been described for some species, e.g. Atlantic cod (Midling *et al.,* 2012).

The size and structure of the swimbladder varies considerably in different teleosts; some taxa, particularly those living in the deep sea or benthic habitats have lost the swimbladder altogether (McCune and Carlson, 2004). Physoclistous (i.e. closed bladder) fish are most susceptible to the effects of barotrauma, (Broadhurst *et al.,* 2006). Physostomous (i.e. open bladder) fish can more readily regulate the amount of gas in their swimbladders by venting it, but may be more susceptible to barotraumatic effects compared to fish lacking a gas bladder (Benoît *et al.,* 2013). This may account for the proportionally higher survival often observed for discarded elasmobranchs and some benthic teleosts that lack closed gas bladders (Depestele *et al.,* 2014; Enever *et al.,* 2008; Laptikhovsky, 2004). A list of marine fish with physoclistous (closed) or physostomous (open) swimbladders is given in Benoît *et al.* (2013).

The **composition and size of the catch** (Robinson *et al.,* 1993) determine how severe the interaction between different animals in the catch will be. It influences the nature and intensity of injuries and thus the associated mortality. For example, Mandelmann and Farrington (2007) observed that larger catch volumes caused greater mortalities among discarded spiny dogfish (*Squalus acanthias,* Appendix IV). Moreover, the crowding density of the catch prior to release (e.g. during slipping in purse-seines) (Tenningen *et al.,* 2012, Appendix IV), and the herding effect that may lead to exhaustion of the fish can result in lower survival (Robinson et al., 1993; de Veen, 1975; Berghahn *et al.,* 1992; Colura and Bumguardner, 2001; Wardle, 1993). It has been suggested that abrasive objects such as spiny fish may cause scale loss among teleosts confined in a codend (Pranovi *et al.*, 2001; Broadhurst *et al.*, 2006) and stinging jellyfish that cannot be excluded from the catch can potentially cause harm (Uhlmann and Broadhurst, 2013). Catch size and composition can also affect handling practices and duration, in turn affecting survival (see Section 7.5.2).

Depredation is the killing and total or partial removal of an animal from a fishing gear by a predator. It has been recognized as an influential factor, especially in gillnets and traps (and also baits)(Uhlmann and Broadhurst, 2013). Where partial removal of an individual has occurred, the remainder will often be discarded. The inclusion of these individuals in estimating a discard survival rate will depend on whether they are being classified as discards.

7.5.2 Handling phase

Technical stressors

Once the catch is brought on deck, the handling phase will influence discard survival. The path of the catch after removal from the fishing gear through the infrastructure onboard can have a major effect on the survival of fish (Berghahn *et al.,* 1992). Different methods exist to haul individual fish on board. Whether the catch is released into a hopper, whether it is pumped or gaffed, the speed, technique and conditions of handling affect animal vitality in the catch. Since exposure to air affects survival (Castro *et al.,* 2003), a quick sorting of the catch generally improves survival. The design of the vessel, and the skills and number of individual crew members on the processing line will therefore have an influence. De-hooking and removing from static nets is easier and faster for experienced fishers. Discards can be temporarily stored on deck, and can be released through a tube above or under the water. This can affect the exposure time to air, altered temperature and light, as well as exposure to seabird predation (Chapman, 1984).

Environmental stressors

Many aquatic organisms suffer from **hypoxia** during **air exposure** (Chapman, 1984) or during **confinement**. The time of air exposure is typically measured as the period between pulling the catch out of the water, until discarding back to the water (Appendix IV). By sorting the catch in water, MacBeth *et al.* (2006) demonstrated that minimizing air exposure reduced discard mortality of undersized prawns (Appendix IV). Hypoxia effects can be confounded with temperature changes to negatively affect survival (e.g. van Beek *et al.,* 1990; Gamito and Cabral, 2003; Giomi *et al.*, 2008; Hyvärinen *et al.,* 2008). Irrespective of the gear type, species-specific and size-dependent tolerances to hypoxia are important biological factors in determining susceptibility to discard survival (Barber and Cobb, 2007; Gisbert and López, 2008; Stewart, 2008). Effects of air exposure may be exacerbated by simultaneous exposure to direct sunlight which can lead to heating and rapid **dehydration**. Exposure to wind or freezing temperature may also increase **dehydration**.

Biological stressors

Within species, **size** matters, with larger fish generally showing higher survival (Neilson *et al.*, 1989; Sangster et al., 1996; Milliken *et al.*, 1999). Increased sensitivity of smaller fish is attributed to greater mass-specific respiration demands (Benoît *et al.,* 2013), to fatigue from swimming during capture (Wardle, 1993) and a reduced ability to avoid injurious contact with the gear and catch (Suuronen *et al.*, 1995, 1996c; Sangster *et al.*, 1996; Wileman *et al.*, 1999; Breen *et al.*, 2007). In addition, body core temperature increases faster in smaller fish (Davis *et al.*, 2001; Davis and Olla, 2001, 2002); an inverse relationship between the rate of body core temperature increase and fish size has been documented (Spigarelli *et al.*, 1977). The mechanisms behind sensitivity towards changing temperatures have not been resolved yet for many species. For example, while flatfish can be both tolerant of hypoxia and temperature change, sablefish are tolerant of hypoxia, but sensitive towards changes in temperature (M. Davis, pers. com.). Salmonids are very sensitive towards temperature changes (Gale *et al.*, 2013), as are clupeids (Lundin *et al.*, 2012).

Injuries will influence survival during the handling phase. For example, removing fish from hooks has a high potential of inflicting tears or puncture to mouthparts or the oesophagus.

As discussed above, the extent of physiological responses to air exposure is species-specific (Benoît *et al*., 2013). The lack of gas exchange during **hypoxia** triggers a cascade of metabolic products that can be measured in the haemolymph, blood and tissue (McMahon, 2001; Davis, 2002). Owing to different respiratory mechanisms, crustaceans are favourably adapted to tolerate anoxic conditions compared to teleost fish. Benoît *et al*. (2013) identified some biological traits such as the presence of deciduous scales, mucus production, body softness and presence of sedentary lifestyles which are indicative of hypoxia sensitivity (Appendix IV). The degree to which such biological resilience occurs may be very specific and associated with certain biological traits (Table 7.2). To illustrate the relationship between stressors and stress responses for discarded organisms, sensitivities towards changes in anoxic conditions, temperature and water depth and their measurable responses have been listed in Table 7.2.

Table 7.2 - List of biological traits and measurable effects associated with sensitivity to hypoxia, changes in temperature and depth.

Sensitivity	Traits	Effect	Species	Reference
Hypoxia	Presence of deciduous scales	Fish with soft scales are sensitive towards desiccation	Atlantic herring, capelin, rainbow smelt	Suuronen et al., (1996); Benoît et al., (2012)
	High mucus production	Mechanizm to prevent desiccation	Hagfish, eel	Benoît et al., (2012)
	Body softness or fragility	Measured with a durometer	Atlantic halibut, mackerel	MacDonald et al., (1996); Benoît et al., (2012)
	Sedentariness	Signs of low metabolic activity (e.g. anaerobic)	Shorthorn sculpin, hagfish	MacCormack and Driedzic (2004); Cox et al., (2011); Benoît et al., (2012)
Temperature	Ventilation rate	Fish under temperature stress breathe faster	Salmonids, Clupeids, Percidae	Gale et al., (2013) Lundin et al., (2012)
	Metabolic rate	Fish below thermal optimum have a reduced metabolizm		
Decompression	Presence and type of gas bladder	Fish with a closed gas bladder are more sensitive towards pressure changes		

7.5.3 Release phase

Technical stressors

The mechanisms by which individuals are released into the water will influence survival. To reduce adverse impacts from discarding, release chutes or recovery boxes may facilitate a less stressful release process (Appendix IV). Allowing species to recover prior to being released has shown to reduce predation (Farrell *et al.*, 2001)

Biological stressor

Successfully evading **predation** depends on the responsiveness of the prey (Fuiman *et al.*, 2006). If reflex responses are impaired (e.g. reduced swimming speed, loss of orientation), then responsiveness will be reduced (Ryer, 2004; Raby *et al.*, 2013). Injuries can affect not only a fish`s ability to evade predators (see below), but also shelter seeking and feeding abilities. Open wounds can facilitate infections by pathogens, particularly in fish already stressed by their interaction with the fishing gear. This can be a direct cause of mortality or result in an increased probability of predation.

7.5.1.1 Environmental stressors

The environment into which the individuals are discarded, and the distance from their natural habitat (**displacement**), will also affect survival chances. Predation rates of discarded fish also depend on variables such as the type of predators present, predator density (Cooke and Philipp, 2004) and predator avidity (Campbell, 2008). Vulnerability to predators is species- and size-specific, for example, large pelagic sharks are shown to have substantial survival rates (>90%), due to their robust nature, their ability to recover quickly from exhaustion, and the low probability of being attacked by larger predators (Megalofonou *et al.*, 2005; McLoughlin and Eliason, 2008).

7.6 Variables : Conclusion

Once a fishery and species has been selected for survival assessment, it is important to identify the relevant stressors that the organisms will be subjected to. This is so that it can be demonstrated that the resultant survival estimates are representative of the fishery and to indentify the main influencing factors on survival, which may be useful in developing mitigation tools. The stressors can be categorized as either technical, environmental or biological.

There are two approaches suggested here to identify relevant stressors for a survival assessment:

5) conceptually tracing an organism's pathway of being i) captured, ii) handled above the water surface, and iii) released back overboard and eventually returning to its habitat; and

6) conduct a literature search or relevant material.

In the first, with sufficient knowledge of the fishery, it is possible to think through the catch and discard process, and identify stressors at each phase. In the second, relevant literature can provide pertinent factors that have been shown to be influential for survival.

The literature search presented here indentified that, among the technical and environmental factors, gear type and configuration, handling, deployment duration, water temperature, depth, and air exposure frequently influenced discard survival levels (Table 7.1). Body size and physical injury were also relevant in explaining variation among discard survival estimates. It should be noted that some important stressors and factors may not have been measured in previous studies. For many stressors taking measurements is straightforward, however, for some, for example, physical condition, predator abundance, distance from suitable habitat, these are more difficult and consequently have been studied to a lesser extent.

There are many variables that can be measured. So the investigator must make a choice as to which will be measured and also the accuracy to which they need to be measured, based on the benefits that will be gained. Quantifying the vitality of the subjects should always be part of the survival assessment; this is covered in detail in Section 4.

8 Using controls in discard survival assessments

Including controls within the survival assessment informs the researcher on the sources of variability for observed mortality. Where survival is less than 100%, unless a control is employed, it cannot be determined whether it was the treatment (having gone through the catch and discard process) or the method (e.g. having been contained or tagged) which was associated with those deaths. The lower the observed survival rate, the higher the potential for method related mortality. In cases where 100% of the treatment subjects survive, it can be concluded that there was no mortality associated with the method. Investigators will therefore want to know that test subjects can be observed without killing a substantial proportion of them.

The acquisition of good controls is one of the most challenging aspects of a survival assessment. The aim should be to use specimens that are as representative of the treatment group as possible but without having undergone the catch and discard process. Appropriate investment in this aspect of the assessment could contribute substantially to the utility of observed survival estimates. A cost-effective approach is to determine the method effects prior to conducting large-scale experiments. This then provides an opportunity to reduce any levels of method related mortality.

Conducting assessments without a control may be an option, where there is high confidence that all or most test subjects will survive and the levels of method related mortality are not a concern. Alternatively, where the acquisition of control subjects is so difficult, it may be more cost-effective to run some initial experiments to ascertain survival rates that are inclusive of method effects. In the absence of controls, valid conclusions can still be reached, but these must make reference to the uncertainty in the level of method related mortality. Controls can also be used to investigate potential benefits of any changes to the treatment of the experimental subjects (e.g. testing mitigation measures, including better handling of discarded animals). This section will briefly explain the scientific principles of using controls in experiments and then discuss how controls can be most appropriately used in survival assessments.

8.1 Principles of Experimental Controls

A control, for the purposes of scientific observation or experimentation, enables the observer to isolate and compare effects of a specific variable upon the experimental units or subjects (e.g. Johnson & Besselsen, 2002). It would typically consist of a subset of experimental subjects that are, ideally, treated in an identical way to the test subjects, with the exception of the test variable.

For this purpose, there are two fundamental types of experimental controls that can be defined:

- ***Negative Controls:*** where no observable response is expected in the control subjects. It demonstrates that there is no effect when there should be no effect; and
- ***Positive Controls:*** where an observable response is expected in the control subjects. That is, it demonstrates that there is an effect when there should be an effect.

8.2 Controls in Survival Assessments

The precise use of controls within an experiment investigating mortality will be dependent upon objective of the experiment (e.g. Johnson and Besselsen, 2002; Pollock and Pine, 2007), for example:

1) providing empirical estimates of survival;
2) identifying suitable surrogate or indirect indices of mortality (e.g. vitality, physiological parameters);
3) comparative trials to assess efficacy of mitigation measures (e.g. experiments with modified gear or operational fishing practices);
4) identifying variables that correlate with observed mortality; and
5) understanding the fundamental fatal mechanisms causing mortality.

There are two principle uses of controls for the types of experiment listed above:

8.2.1 Method controls:

i.e. negative controls to demonstrate that the methods (e.g. captive observation or tagging) used to observe the experimental subjects are not inducing any of the observed mortality. As such they will often also be referred to as “captivity” or “tagging” controls, to reflect the nature of the experiment. The aim of these controls is to demonstrate that there are no observable, fatal, observation-related effects, by using a negative control to isolate the stressors associated with the observation technique. It is applicable to all of the above examples. This is arguably the most important application of a control in a survival assessment, in that it attempts to validate the observation technique as capable of determining the effect of different variables on mortality without bias.

The interpretation of experimental results when method (negative) controls are used is as follows:

Control	Treatment	Conclusion
0	1	Significant Treatment Effect
0	0	No Significant Treatment Effect
1	1 or 0	Inconclusive - confounding effects

Effect observed = 1

No effect observed = 0

As part of the prioritization process (see Section 2.5), it would be useful to collect experimental subjects for preliminary tests as method (negative) controls. This process will allow the experimenter to test appropriate techniques for acquiring and holding, or tagging, subjects to determine the effects of these methods upon survival. It is likely that such results would be very informative, particularly in cases where it proves impossible to collect and observe specimens without a substantial mortality.

8.2.2 Comparative controls:

i.e. positive controls to isolate or compare the effects of specific experimental stressor treatments. This approach is applicable to cases iii) to v) above. Practically, it is generally easier to obtain a valid comparative (positive) control compared to a method (negative) control, because the control subjects can be caught using the same technique as the test subjects. Also, it is implicitly accepted that there will be a method effect in both the control and test subjects. However, this presents an important limitation, in that it only allows for relative comparison, unless the relationship between the stressors and mortality is precisely understood and predictable. That is, it generally allows us to conclude whether the treatment has a significantly greater or lesser effect than the control (or alternative treatment), but we cannot make any inferences about what the experimental treatment mortality would be in the absence of a method effect.

The interpretation of experimental results when comparative (positive) controls are used is as follows:

Control	Treatment	Conclusion
Control > Treatment		Treatment effect sig. < Control
Control < Treatment		Treatment effect sig. > Control
0	0	No sig. treatment effect
Control ≈ Treatment		No sig. treatment effect, if +ve control shows no confounding effects. Otherwise, inconclusive.

8.3 Properties of Effective Controls

When using controls within an experiment there are a number of general properties that experimenters should strive to attain:

8.3.1 Measurability

As with any experimental variable, there should be a clearly defined response that can be reproducibly measured. Survival experiments measure effects upon mortality, so the measurable endpoint is clearly "death". However, for some species and in some situations, "death" can be challenging to define or observe, and can easily lead to random error and biases within the experimental results. This can be avoided by using clear, unambiguous criteria to assess the status of the individual (e.g. Davis 2007, Benoit *et al.,* 2012). These criteria should preferably be binary, for example reflexes, which can be measured as present or not (see Davis and Ottmar 2006; and Section 4).

8.3.2 Predictability –

Ideally, the type of control (i.e. whether it is positive or negative) should be defined before the experiment (*post hoc* experimental design can lead to subjective interpretation). If it is a positive control, the experimenter should also be able to predict the likely resultant mortality, or least whether it should be larger or smaller than the treatment. Without this approach, it is impossible to define testable hypotheses for the experiment.

8.3.3 Representative experimental conditions

The treatment and control subjects should experience identical experimental conditions, with exception of the treatment effect. Typical examples are identical monitoring periods, identical holding conditions (cages, temperature, water quality, season). This requires full control over all aspects of the experimental design and protocol, which in reality is difficult to achieve, particularly outside the laboratory – where natural *in situ* conditions will often introduce random errors.

8.3.4 Representative subject populations

The test and control subjects should ideally be identical, or at least comparable, with respect to key biological variables that could affect mortality, e.g., length, age, physical condition (condition factors or indices, length/weight), sexual maturity, feeding status, parasite/disease loading and genotype. In reality however it is very difficult to select two identical groups of experimental subjects. Therefore, to minimize the potential for any biases or systematic errors, experimental treatment and control subjects should be randomized by selecting the test and control subjects randomly from the same "population", e.g. from same localized area, depth, time frame and species (see Section 8.4).

8.3.5 Double Blind Controls

An effect method for avoiding non-representative conditions and observer bias in experiments is to use double blind controls; where neither the test subject nor the experimenter is cognisant of whether a particular experimental unit is a test or control subject, until the experiment is completed. This has clear benefits in avoiding systematic errors or biases resulting from the experimenters' preconceived expectations and differential behaviour towards the experimental subjects.

8.4 Acquiring Controls

There are a number of possible sources to acquire controls for survival assessments:

> *Wild-caught using "benign" capture*. Commonly used are barbless hooks and traps or pots (see e.g. Breen *et al*. 2007; Lundin *et al*,. 2012). But few capture methods are truly benign. It is also important to realize that different gears have different selective properties, which undermines randomization of the subject population.
>
> *Wild-caught and quarantined*, i.e. stored in captivity until the primary mortality after capture levels off. However, this method selects the fittest fish, which again undermines randomization.
>
> *Hatchery reared or domesticated fish*. This source of control fish should be avoided if possible as domesticated fish may have different stress responses in captivity than wild fish, and may also react differently to stimuli. and stressors

In reality, the acquisition of good controls is one of the most challenging aspects of a survival assessment and there are few examples of effective controls for wild fish populations in the scientific literature. However, appropriate investment in this aspect of the assessment will contribute substantially to the effective selection of appropriate candidate species and fisheries, as well as the utility of resultant survival estimates.

9 Data Analysis in Discard Survival Assessments

This section will be completed at the next WKMEDS meeting in the fourth quarter of 2014. The final version of this section will include information on:

- Experimental Design
    - Components of an Experiment
    - Defining the number of replicates & sample sizes
- Analysing Survival Data
    - What is Binary Data?
        - Binomial Distribution & Confidence Intervals
        - Censored Data
    - Modelling Binary Data
        - Generalized Linear Models (GLM)
        - Generalized Linear Mixed Models (GLMM)
        - Survival/Failure Analysis
            - Non-parametric Models (e.g. Kaplan-Meier method)
            - Parametric Models (e.g. Exponential & Weibull models)
- Presenting & Utilizing Survival Estimates
    - Vitality Correlated Survival
    - Conditional Probability
    - Examples of discard survival being used in stock assessments and fisheries management.

Adjusting for method control mortality

In recent scientific literature there are examples of survival estimates being adjusted or "corrected" with respect to estimates of mortality/survival from method (negative) controls. This has been done by either: i) subtracting the method control mortality from the observed treatment estimate; or ii) by dividing the observed treatment survival estimate by the method control survival estimate. The rationale behind this is to remove any biases introduced by mortality associated with the method (e.g. captive observation or tagging). While in principle this appears to be a rational "correction", unfortunately this has the potential to introduce errors and biases itself.

Simply subtracting one proportion from another is mathematically incorrect, because proportions are bounded by 0 and 1. This can lead to impossible "corrected" estimates of survival, i.e. negative proportions (for example if 50% of control subjects died and 40% of treatment subjects died, the subtraction method would give a corrected survival rate of -10%). More mathematically acceptable approaches can be argued with conditional probability and with instantaneous mortality rates (e.g. Pollock and Pine, 2007). However, these approaches assume there is no interaction between the treatment and observation effects, which in reality is unlikely to be true (Pollock and Pine, 2007).

To date, there is no satisfactory method to adjust the treatment data using the control data and further focus on this issue is planned for the next WKMEDS meeting. Therefore, it is currently recommended that when substantial mortality is observed in the control subjects, this should not be used to adjust the treatment survival values. Instead, the magnitude of this control mortality should be used as a measure of the validity of the observation method, where mortalities close to zero suggest a more valid method for accurately estimating discard survival.

10 Ethics and relevant legislation

It may be necessary to apply for a licence for both the project and the staff handling the animals. Please note these applications can be time consuming and should be done in an early stage in the planning of the assessment.

Details on EU legislation regarding experiments with animals can be found at:

- http://ec.europa.eu/environment/chemicals/lab_animals/home_en.htm
- http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm

11 Health and Safety

An important part of the planning and execution of any scientific work is ensuring the safety of personnel directly involved in the operations, as well as anybody who could be indirectly affected by them.

National and regional guidelines and regulations should be abided by when planning and conducting survival assessments, and further information on this can be found at the European Agency for Safety and Health at Work (EU-OSHA):

https://osha.europa.eu/en

A number of key hazards will need to be considered when planning and conducting survival assessments, including:

- Operations on commercial fishing vessels
- Handling dangerous animals
- Bio-security
- Diving operations
- Stability of vessels with observation tanks
- Handling/moving tanks during observations
- Releasing tagged fish.

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Appendix I: Explanatory variables: Glossary of terms:

Air exposure: the time spent out of the water on deck exposed to air (also called 'deck time').

Air temperature: refers to the temperature measured on deck or in the laboratory.

Behaviour: behaviour of the studied species (evasion reflexes, movement, competition, antagonistic behaviour).

Body size: length measurement of discarded specimen (related to sensitivity of specimen and body core temperature).

Catch composition: list of species recorded in the catch, keeping in mind potential deleterious interactions with study organisms (scale abrasion from spiny fish, or stings from jellyfish).

Catch density: number of individuals in the catch, per unit of volume (e.g. herding effect, crowding density).

Catch volume: amount of catch, expressed as a volume.

Deployment duration: refers to the period of time fishing gear is being submerged underwater and actively fishing (e.g. towing time; haul-back time; 'set duration'; fighting time, and 'soak time').

Depth: depth from which the catch is hauled up (related to changes in hydrostatic pressure, light intensity, water temperature, salinity and dissolved oxygen).

Dissolved oxygen: amount of oxygen (O_2) dissolved in water (related to hypoxia).

Gear configuration: materials used and their arrangement/rigging (e.g. yarn stiffness or surface, knot thickness, mesh size, mesh shape, dimensions, or hook type, hook design and size); includes gear modifications to improve selectivity (e.g. Nordmøre grids, or guiding/escape panels).

Gear operation: particular mechanizms describing the way gear is being deployed and retrieved (e.g. haulback operations with purse-seiners).

Gear type: refers to distinct gear configurations that classify gears into different groups (e.g. trawls, hook & line, gillnets, trammelnets, purse-seine).

Sex: sexual morphological characteristics of the discarded specimen (male, female, hermaphrodite).

Handling: describes all operational steps associated with the sorting and processing of the catch on board a vessel, including mechanical processing machinery (e.g. sorting procedure, drop height of discards, gaffing, crew experience).

Infection: invasion by and multiplication of pathogens in or on body tissue, which may lead to a disease through a variety of cellular or toxic mechanizms.

Injury: describes the size and severity of any potential external or internal injuries (e.g. scale loss, lesions, or wounds).

Light: light intensity in water and/or air.

Location: location where the catch is taken from, referring to latitude/longitude and related to sediment type.

Physical condition: specific condition of discarded specimen (e.g. vitality, injuries, reproductive condition).

Predation: risk of being eaten by a predator (also described by predator type, predator density, predator avidity, initial responsiveness of prey to a potential predator).

Recapture: the re-occurrence of a capture-and-release event. In intensively fished areas a discarded organism may be recaptured.

Salinity: dissolved salt content in the water.

Season: time of year in relation to weather conditions, or physical condition of species to be discarded (e.g. reproductive condition, air and/or water temperature, sea state, passage of storms.

Sediment type: type of sediment at the location where the catch is taken from (e.g. rock/sand bottom).

Species: refers to phenotype of species, i.e. being more robust or fragile (e.g. spines, shells, carapaces, presence/absence of a swimbladder, deciduous scales).

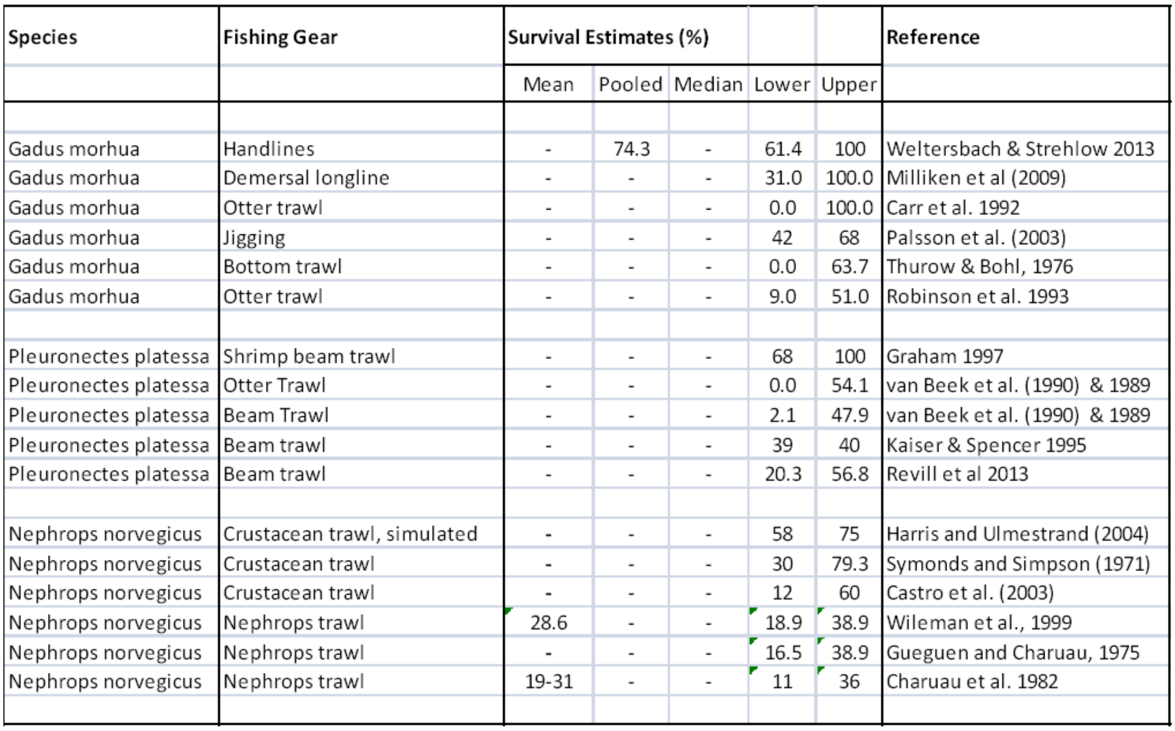
Stress: response to a stressor such as an environmental condition or a stimulus. Represents a wide range of physical responses that occur as a direct effect of a stressor causing an upset in the homeostasis of the body. Due to a disruption of the physical equilibrium, the body responds by stimulating the nervous, endocrine, and immune systems.

Water temperature: temperature of the water, measured *in situ* or in the laboratory (e.g. temperature change, thermocline, water surface temperature).

Weather: refers here to temperature and precipitation patterns.

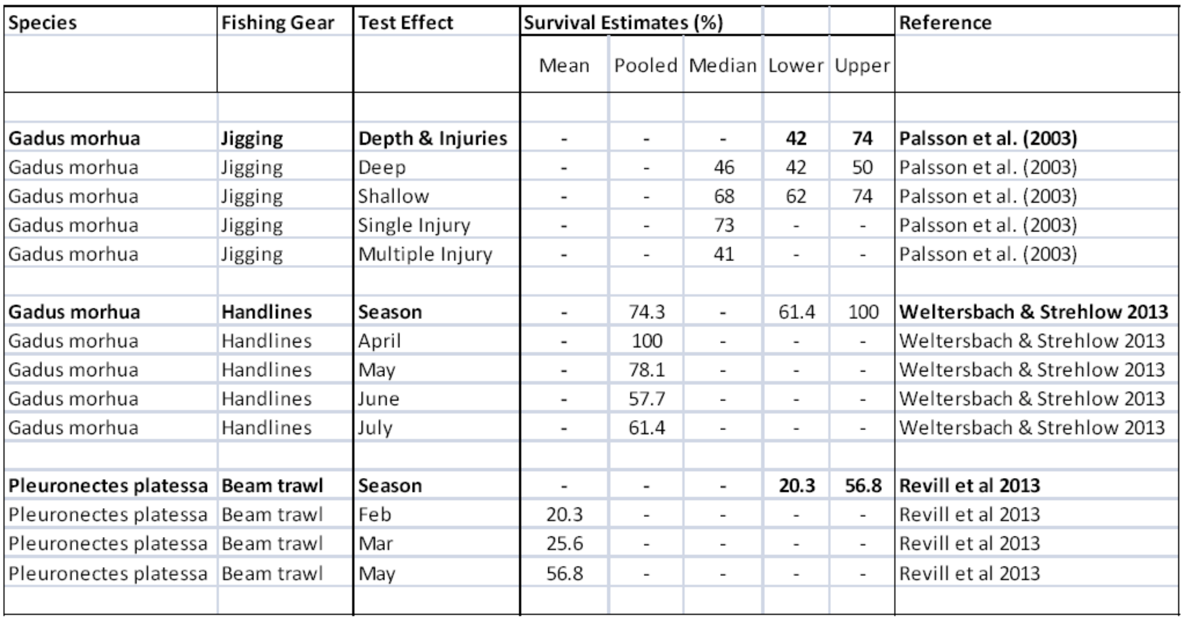
Year: if a study was annually replicated.

Appendix II: Examples of discard survival estimates, by species & fishing gear



Species	Fishing Gear	Survival Estimates (%)					Reference
		Mean	Pooled	Median	Lower	Upper	
Gadus morhua	Handlines	-	74.3	-	61.4	100	Weltersbach & Strehlow 2013
Gadus morhua	Demersal longline	-	-	-	31.0	100.0	Milliken et al (2009)
Gadus morhua	Otter trawl	-	-	-	0.0	100.0	Carr et al. 1992
Gadus morhua	Jigging	-	-	-	42	68	Palsson et al. (2003)
Gadus morhua	Bottom trawl	-	-	-	0.0	63.7	Thurow & Bohl, 1976
Gadus morhua	Otter trawl	-	-	-	9.0	51.0	Robinson et al. 1993
Pleuronectes platessa	Shrimp beam trawl	-	-	-	68	100	Graham 1997
Pleuronectes platessa	Otter Trawl	-	-	-	0.0	54.1	van Beek et al. (1990) & 1989
Pleuronectes platessa	Beam Trawl	-	-	-	2.1	47.9	van Beek et al. (1990) & 1989
Pleuronectes platessa	Beam trawl	-	-	-	39	40	Kaiser & Spencer 1995
Pleuronectes platessa	Beam trawl	-	-	-	20.3	56.8	Revill et al 2013
Nephrops norvegicus	Crustacean trawl, simulated	-	-	-	58	75	Harris and Ulmestrand (2004)
Nephrops norvegicus	Crustacean trawl	-	-	-	30	79.3	Symonds and Simpson (1971)
Nephrops norvegicus	Crustacean trawl	-	-	-	12	60	Castro et al. (2003)
Nephrops norvegicus	Nephrops trawl	28.6	-	-	18.9	38.9	Wileman et al., 1999
Nephrops norvegicus	Nephrops trawl	-	-	-	16.5	38.9	Gueguen and Charuau, 1975
Nephrops norvegicus	Nephrops trawl	19-31	-	-	11	36	Charuau et al. 1982

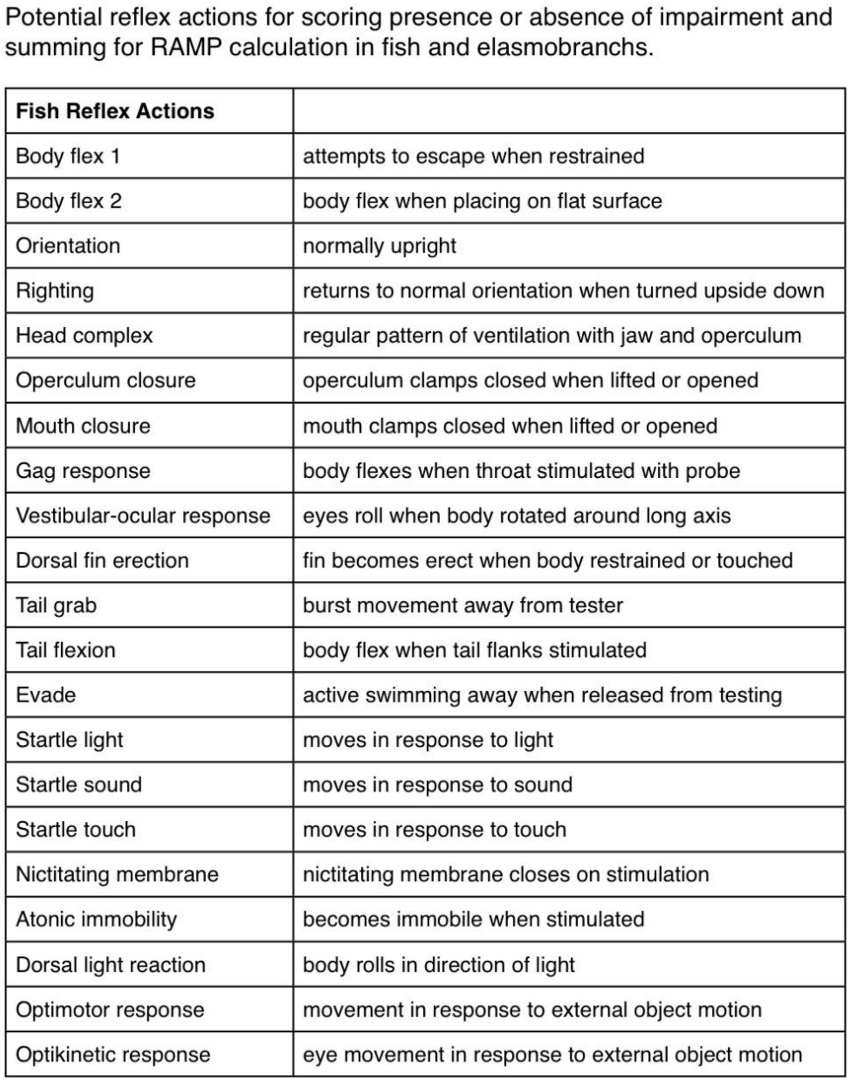
Table 1 - Examples of discard survival estimates, by species & fishing gear (from Revill, 2012).



Species	Fishing Gear	Test Effect	Survival Estimates (%)					Reference
			Mean	Pooled	Median	Lower	Upper	
Gadus morhua	**Jigging**	**Depth & Injuries**	-	-	-	**42**	**74**	**Palsson et al. (2003)**
Gadus morhua	Jigging	Deep	-	-	46	42	50	Palsson et al. (2003)
Gadus morhua	Jigging	Shallow	-	-	68	62	74	Palsson et al. (2003)
Gadus morhua	Jigging	Single Injury	-	-	73	-	-	Palsson et al. (2003)
Gadus morhua	Jigging	Multiple Injury	-	-	41	-	-	Palsson et al. (2003)
Gadus morhua	**Handlines**	**Season**	-	74.3	-	61.4	100	**Weltersbach & Strehlow 2013**
Gadus morhua	Handlines	April	-	100	-	-	-	Weltersbach & Strehlow 2013
Gadus morhua	Handlines	May	-	78.1	-	-	-	Weltersbach & Strehlow 2013
Gadus morhua	Handlines	June	-	57.7	-	-	-	Weltersbach & Strehlow 2013
Gadus morhua	Handlines	July	-	61.4	-	-	-	Weltersbach & Strehlow 2013
Pleuronectes platessa	**Beam trawl**	**Season**	-	-	-	**20.3**	**56.8**	**Revill et al 2013**
Pleuronectes platessa	Beam trawl	Feb	20.3	-	-	-	-	Revill et al 2013
Pleuronectes platessa	Beam trawl	Mar	25.6	-	-	-	-	Revill et al 2013
Pleuronectes platessa	Beam trawl	May	56.8	-	-	-	-	Revill et al 2013

Table 2 - Examples of discard survival estimates (from Table 1), disaggregated with respect to key explanatory variables (i.e. Depth, degree of injury and season) (adapted from Revill, 2012).

Appendix III. List of reflex actions, barotrauma symptoms, and injuries that have been scored in previous RAMP studies.



Potential reflex actions for scoring presence or absence of impairment and summing for RAMP calculation in fish and elasmobranchs.

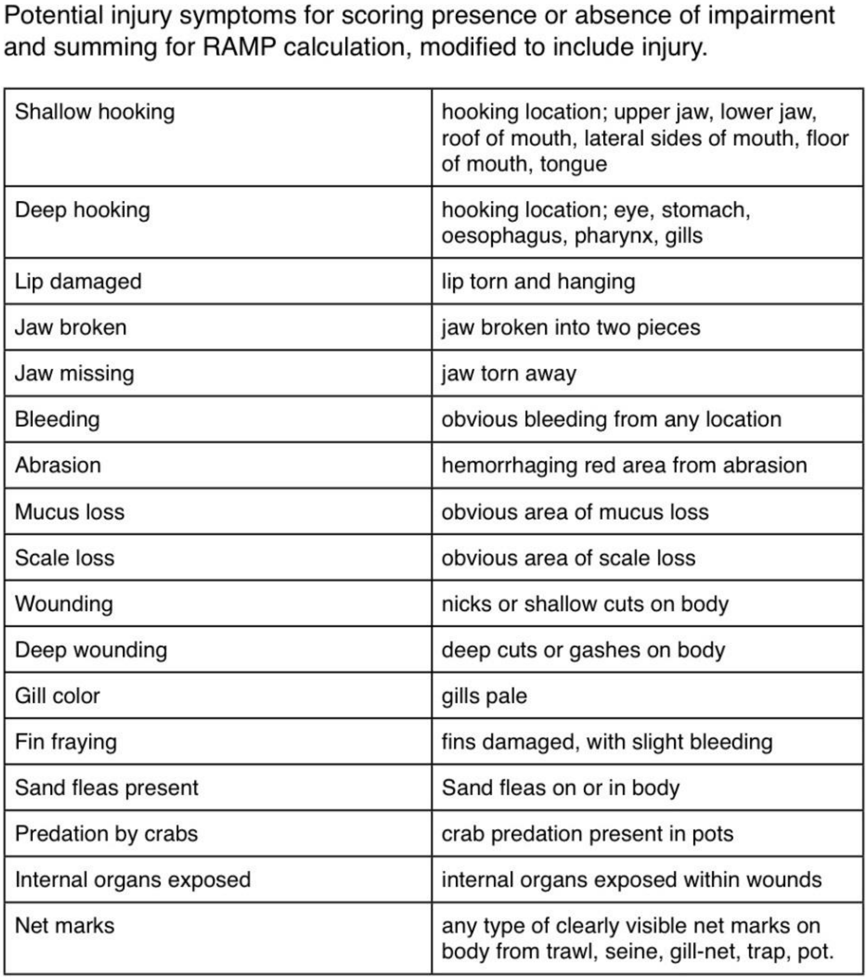
Fish Reflex Actions	
Body flex 1	attempts to escape when restrained
Body flex 2	body flex when placing on flat surface
Orientation	normally upright
Righting	returns to normal orientation when turned upside down
Head complex	regular pattern of ventilation with jaw and operculum
Operculum closure	operculum clamps closed when lifted or opened
Mouth closure	mouth clamps closed when lifted or opened
Gag response	body flexes when throat stimulated with probe
Vestibular-ocular response	eyes roll when body rotated around long axis
Dorsal fin erection	fin becomes erect when body restrained or touched
Tail grab	burst movement away from tester
Tail flexion	body flex when tail flanks stimulated
Evade	active swimming away when released from testing
Startle light	moves in response to light
Startle sound	moves in response to sound
Startle touch	moves in response to touch
Nictitating membrane	nictitating membrane closes on stimulation
Atonic immobility	becomes immobile when stimulated
Dorsal light reaction	body rolls in direction of light
Optimotor response	movement in response to external object motion
Optikinetic response	eye movement in response to external object motion

Potential reflex actions for scoring presence or absence of impairment and summing for RAMP calculation in crustaceans.

Crustacean Reflex Actions	
Abdominal turgor	abdomen extends horizontally or tail flip
Abdominal extension	abdomen extends outward
Leg motion	leg moves in held animal
Leg retraction	leg retracted in held animal
Leg extension/flare	leg spread wide, extended in held animal
Pleopod motion	pleopods retract when stimulated
Maxilliped motion	maxillipeds move when stimulated
Maxilliped retraction	maxillipeds retract in posterior direction
Antenna response	antenna moves when stimulated
Eye turgor	eye stalk moves when stimulated
Eye retraction	eye stalk retracts when stimulated
Chela closure	chela closes when stimulated
Aggressive posture	assumes aggressive defense posture when released

Potential barotrauma symptoms for scoring presence or absence of impairment and summing for modified RAMP calculation.

Tight abdomen	Abdomen swollen, tight to touch
Bulging membrane	Bulge in branchiostegial membrane
Air in membrane	Air spaces or bubbles visible in branchiostegial membrane
Exophthalmia	Eyes distended outwards from head
Corneal gas bubbles	Air present in eye or membrane covering eye
Stomach eversion	Eversion of esophageal tissue (at least 1 cm in diameter) into buccal cavity
Prolapsed cloaca	Intestine protruding out of anus
Subcutaneous gas bubbles	Air under tissue (fins, gums, body surface)
Subcutaneous hemorrhaging	Blood under tissue (fins, gums, body surface)



Potential injury symptoms for scoring presence or absence of impairment and summing for RAMP calculation, modified to include injury.

Shallow hooking	hooking location; upper jaw, lower jaw, roof of mouth, lateral sides of mouth, floor of mouth, tongue
Deep hooking	hooking location; eye, stomach, oesophagus, pharynx, gills
Lip damaged	lip torn and hanging
Jaw broken	jaw broken into two pieces
Jaw missing	jaw torn away
Bleeding	obvious bleeding from any location
Abrasion	hemorrhaging red area from abrasion
Mucus loss	obvious area of mucus loss
Scale loss	obvious area of scale loss
Wounding	nicks or shallow cuts on body
Deep wounding	deep cuts or gashes on body
Gill color	gills pale
Fin fraying	fins damaged, with slight bleeding
Sand fleas present	Sand fleas on or in body
Predation by crabs	crab predation present in pots
Internal organs exposed	internal organs exposed within wounds
Net marks	any type of clearly visible net marks on body from trawl, seine, gill-net, trap, pot.

Appendix IV. Details about how to measure and analyze some of the relevant factors in specific fisheries.

Factor	**Measurement**	**Data and analysis**	**Species**	**Gear type**	**Reference$^{F/L}$**
Air exposure	Time to mortality	Survival analysis using a modified Kaplan-Meier method	Various species	Bottom trawl	Benoit et al., (2013)
Catch volume	Discards as a proportion of total catch	GLMM catch comparison (Holst and Revill)	Skate (*Rajidae*)	Bottom trawl	Enever et. al., (2009)
Air temperature	Summer: 28°C, winter: 9°C	Mann–Whitney U-test	Sandy swimming crab (*Liocarcinus depurator*)	Rapido trawl	Giomi et al., (2008)
Injury	Each flank of the fish was divided into eight regions that could be delimited visually, and scale loss in each region was evaluated on a level of 0 to 10 (corresponding to 0 to 100% scale loss). (L)	Mean level of scale loss among regions and flanks was used to describe fish scale loss (expressed as percentage).	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2008)
Sorting and handling	Mild and extreme of the most plausible range of existing commercial proce-	Two-sample Kolmogorov-Smirnov test (for length distributions)	School prawns, (*Metapenaeus macleayi*)	Seines and trawl	Broadhurst et al., (2007)^{F}

	dures				
Catch volume	Catch weight	Percentage of mortality after 72h in pens. ANOVA-stepwise regression: %_mortality~tow weight	Spiny dogfish (Squalus acanthias)	Bottom trawl	Mandelman and Farrington, (2007)[F]
Air exposure	Presence or absence of "wet treatment" during catch process	Binary data (dead/alive)vs.treatment (dry or wet handling process) - Student-Newman-Keuls and/or logistic model	School prawn (*Metapenaeus macleayi*)	Bottom trawl	MacBeth et. al., (2006)[F]
Deployment duration	Duration ≤6h and >6h	Maximum likelihood analysis of variance for the log-linear mode	Norway lobster, (*Nephrops norwegicus*)	Otter trawl	Castro et al., (2003)
Air temperature	Season increased mortality in warm months	Maximum likelihood analysis of variance for the log-linear mode	Norway lobster, (*Nephrops norwegicus*)	Otter trawl	Castro et al., (2003)
Deployment duration	Duration ≤6h and >6h	Maximum likelihood analysis of variance for the log-linear mode	Norway lobster, (*Nephrops norwegicus*)	Commercial trawl	Castro et al., (2003)
Deployment duration	Haul durations 10, 20 and 30 min	ANOVA	Brown shrimp (*Crangon crangon*)	Beam trawl	Gamito and Cabral, (2003)

Sorting and handling	Sorting containers were either wooden, plastic or metallic, dark or light-coloured	ANOVA	Brown shrimp (*Crangon crangon*)	Beam trawl	Gamito and Cabral, (2003)
Air temperature	Sorting times 5 and 10 min	ANOVA	Brown shrimp, (*Crangon crangon*)	Beam trawl	Gamito and Cabral, (2003)
Sorting and handling	Time 0-55 min	ANOVA	Lingcod (*Ophiodon elongates*)	Commercial trawl	Parker et al., (2003)
Deployment duration	Tow duration 35-300 min	ANOVA	Lingcod (*Ophiodon elongates*)	Commercial trawl	Parker et al., (2003)
Size	Size <66 and ≥66 cm	ANOVA	Lingcod (*Ophiodon elongates*)	Commercial trawl	Parker et al., (2003)
Air exposure and air and water temperature	Duration of air exposure under various temperature	One-tailed sign test to check effect of size on mortality under various temperature conditions	Lingcod (*Ophiodon elongatus*)	Towed net	Davis and Olla, (2002)
Gear deployment	Tow duration Catch weight	Logistic regression between tow duration, catch weight an d fish length and mortality.	Sea snakes (various species)	Prawn trawl	Wassenberg et al., (2001)
Gear type	Simulated capture by either gillnets or longlines	Comparison of struggling profiles with two-sample t-tests, ANOVA	Port Jackson sharks (*Heterodontus portusjacksoni*) and gummy sharks	Gillnet and longline	Frick et al. 2010

			(*Mustelus antarcticus*)		
Gear configuration	Gillnet tension was increased by using larger floats and heavy, weighted footrope; entanglement modus of sharks was classified into four categories.	Effect of the entanglement modus on shark mortality was determined by Chi-squared test. ANOVA for comparing entanglement modus and gillnet treatment.	Blacknose shark (*Carcharhinus acronotus*) et al.	Gillnet	Thorpe and Frierson, (2009)
Injury	Wound type was recorded as either sealed or unsealed	Logistic regression model	Blue swimmer crab (*Portunus pelagicus*)	Gillnet	Uhlmann et al., (2009)
Size	Fork length was measured and found to be negatively correlated with the proportion dying	Mixed-effects logistic models	Surf bream (*Acanthopagrus Australis*)	Gillnet and beach seine	Broadhurst et al., (2008)
Depth	Capture depth, barotrauma relief methods	Multi-factor GLM	Red emperor (*Lutjanus sebae*)	Hook and line	Brown et al., (2010)
Gear configuration	Hook type (J-hook vs. Circle hook)	Logistic regeression and Chi-squaredd test	*Trachynotus ovatus*	Hook and line	Alós, (2009)
Gear configuration	Lure/bait type	Logistic regression	Northern Pike (*Esox lucius*)	Hook and line	Arlinghaus et al., (2008)

Dissolved oxygen	ATP, Phosphocreatine (PCr) and glycogen levels as proxy for stress	ANOVA	Largemouth bass (*Micropterus salmoides*)	Hook and line	Suski et al., (2006)
Water temperature	ATP, Phosphocreatine (PCr) and glycogen levels as proxy for stress	ANOVA	Largemouth bass (*Micropterus salmoides*)	Hook and line	Suski et al., (2006)
Deployment duration	Rapid vs. extended capture	Multiple regressions	Rainbow trout (*Oncorhynchus mykiss*)	Hook and line	Meka and McCormick, (2005)
Air exposure	Swimming activity after different air exposure durations	ANOVA	Brook trout (*Salvelinus fontinalis*)	Hook and line	Schreer et al., (2005)
Handling	Retention in fishing tournaments	ANOVA	Largemouth bass (*Micropterus salmoides*)	Hook and line	Suski et al., (2003)
Size	Total length	Radio tagging, no statistical analysis of survival rates	Atlantic salmon (*Salmo salar*)	Hook and line	Thorstad et al., (2003)
Season	Locomotory activity of nesting and non-nesting fish	Paired t-test	Largemouth bass (*Micropterus salmoides*)	Hook and line	Cooke et al., (2000)
Handling	Levels of angling experience	Logistic regression	Striped bass (*Morone saxatilis*)	Hook and line	Diodati and Richards (1996)

Gear operation	Active vs. passive fishing	Logistic regression	Rainbow trout (*Oncorhynchus mykiss*)	Hook and line	Schisler and Bergersen (1996)
Deployment duration	Soak time	Tagging (PAT)/Logistic regression	Blue shark (*Prionace glauca*)	Longline	Campana et al., (2009)
Water temperature		Tagging (PAT)/Logistic regression	Blue shark (*Prionace glauca*)	Longline	Campana et al., (2009)
Size	Fork length	Tagging (PAT)/Logistic regression	Blue shark (*Prionace glauca*)	Longline	Campana et al., (2009)
Depth		Cage experiment/Logistic regression	Atlantic cod (*Gadus morhua*)	Longline	Milliken et al., (2009)
Gear modification	Hook type (J-hook vs. Circle hook)	Vitality assessment/Cochran–Mantel–Haenszel Chi-squared test	Several tropical and subtropical pelagic species	Longline	Kerstetter and Graves, (2006)
Area	Catch position	Vitality assessment/Linear Regression with transformed data	Blue shark (*Prionace glauca*)	Longline	Diaz and Serafy, (2005)
Season		Vitality assessment/Linear Regression with transformed data	Blue shark (*Prionace glauca*)	Longline	Diaz and Serafy, (2005)
Sex	Sex	Vitality assessment/Logistic regres-	Skate (Raja sp. anon.)	Longline	Endicott and Agnew, (2004)

		sion			
Handling	Method of removal from line	Vitality assessment/Logistic regression	Skate (Raja sp. anon.)	Longline	Endicott and Agnew, (2004)
Position on line		Vitality assessment/Logistic regression	Skate (Raja sp. anon.)	Longline	Endicott and Agnew, (2004)
Temperature, air		Vitality assessment/Logistic regression	Skate (Raja sp. anon.)	Longline	Endicott and Agnew, (2004)
Weather	Windspeed in Beaufort scale	Vitality assessment/Logistic regression	Skate (Raja sp. anon.)	Longline	Endicott and Agnew, (2004)
Depth		Cage experiment/Logistic regression	Atlantic cod (*Gadus morhua*)	Jigging machine	Pálsson et al., (2003)
Predation	Predator approach and nearest-neighbour distance measured in random frames, using image processing programme.	Comparison of nearest-neighbour distances between treatment and control by Kruskal–Wallis test followed by pairwise multiple comparison among groups using Dunn's method	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2013)

(Reproductive) condition	Monitoring of mortality, behavior and blood parameters in different treatments. Condition factors were based on weight and length of fish (L)	ANOVA, Tukey's HSD model for pairwise comparison, Tamhane's posthoc test	Herring (*Clupea harengus*)	Purse-seine	Olsen et al. (2012)
(Reproductive) condition	Measure lengths and weights of fish. Fulton's condition factor: C = Weight/(Length^3) × constant (1000). (F)	Regression analysis to evaluate: effect of time spent in crowded net pens on the condition factor and the effect of fish condition on the blood parameter levels	Herring (*Clupea harengus*)	Purse-seine	Tenningen et al., (2012)
Catch volume	"Reducing the volume in a net and increasing fish density. While fully crowded, the dimensions of the net were estimated using a measuring pole and the shape of the net	Effects of crowding density (number/m3) and time on blood parameters and number of dead fish. Also oxygen levels were monitored in the net pens.	Herring (*Clupea harengus*)	Purse-seine	Tenningen et al 2012., (Similar approach for mackerel [Huse and Vold 2010] and sardine [Marcalo et al 2010, 2013])
Water temperature	Seasonal variation of water temperature in captivity tanks was used as a factor dur-	ANOVA table was built on a linear model of each relevant	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2010)

	ing fishing simulation experiments	variable as a function of fishing time and temperature (both as factor variables), and the interaction term. Effect of temperature on survival was modelled with Kaplan–Meier (KM) survival estimators			
Catch composition	amount of species in the catch, different from the studied species	GLM and GAM analyses	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2008)
Physical injury/stress	at the surface was recorded by photographs for later estimation of the volume. Time of crowding was varied. (F/L)"	Mean level of scale loss among regions and flanks was used to describe fish scale loss (expressed as percentage).	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2008)
Physical injury/stress	Each flank of the fish was divided into eight regions that could be delimited visually, and scale loss in each region was evaluated on a	GLM analysis	Sardine (*Sardina pilchardus*)	Purse-seine	Marcalo et al., (2008)

	level of 0 to 10 (corresponding to 0 to 100% scale loss). (L)				

Appendix V: Examples of data sheets used to collect information on various technical, environmental and biological variables

Nephrops survival survey	**Survey information**

VESSEL	
Name	*Length*
TRAWL CODEND	
Twine material	*Twine diameter*
Number of mesh	*Twine* ☐ simple ☐ double
Protections ☐ Yes ☐ No	
Selective device ☐ Yes ☐ No	
DECK	
- Dimension of sorting area on board : - Height working area : - Dimension of sorting table : Drawing of sorting area:	
CATCH SORTING ORGANIZATION (Crew)	

-- Number of crew members :

-- Sorting table : ☐ Yes ☐ No

-- Discard : ☐ all along the sorting process ☐ after the sorting of the catch

Nephrops survival survey			**Fishing operation information**
Date	N° haul	*Type of seabed*	

Trawl Shooting	
Start of fishing operation	*Depth*
Latitude	*Longitude*
Trawl Hauling	
End of fishing operation	*depth*
Latitude	*Longitude*
Time codend on the deck	

CATCH			
		Landed (kg)	Discarded (kg)
Nephrops			
Fish, others			

Discarded Nephrops after sorting the catch		
Nephrops	Number alive	Number dead
ENVIRONNEMENT		

Water Temp. air :		*Predation (e.g. : bird)*
Atmospheric pressure :		
Humidity :		
Sea state :		
OBSERVATIONS		

Nephrops survival survey	Individual information

Fishing operation				After re-immersion
Date	***N° Haul***	*N° Flag*	*Time haul on board*	*Date bag on board*
Trawl ☐ **Starboard** ☐ **Port side**		Sorting starting time	*Sorthing ending time*	*Time bag on board*

Bag N°1 BEFORE **re-immersion**				
N° tube	Time	Vitality[1]	Sex	Phys. state[2]

Bag N°1 **AFTER** Re-immersion					
N° tube	Time	Length	Vitality[1]	Sex	Phys. state[2]

Observations				

Observations					

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[1] Vitality : H = Healthy, M = Moribund, D = Dead

[2] Physical state : OK, 1P = 1 pincer, 0P = 0 pincer, E = female with eggs, other information should be noted as '*observations*'

ANNEX 1 Background Information

1. Background

ICES established a Workshop on Methods for Estimating Discard Survival (WKMEDS), in January 2014, in response to a request from the European Commission to address the urgent need for guidance on methods, as identified by STECF EWG 13-16 (STECF, 2014).

EU Member States and Advisory Councils are interested in commissioning survival studies to investigate the feasibility of exemptions to the Landings Obligation, under Art. 15, para. 2b of the new EU Common Fisheries Policy. There are practical and scientific limitations to the methods currently available for estimating discard survival (ICES, 1995, 1997, 2000, 2004 & 2005; Revill, 2012; Gilman et al., 2013). Therefore, there is an urgent requirement for the provision of guidelines, or identification of best practice, for undertaking discard-survival studies.

2. Terms of Reference

This workshop was chaired by Mike Breen (Norway) and Thomas Catchpole (UK), and will work by correspondence as well as a series of meetings during 2014–16 to:

a) Develop guidelines and where possible identify best practice for undertaking discard survival studies (using the framework detailed in the report of STECF Expert Working Group EWG 13–16) (2014 Workshop);

b) Identify approaches for measuring and reducing, or accounting for, the uncertainty associated with mortality estimates;

c) Critically review current estimates of discard mortality, with reference to the guidelines detailed in 1, and collate existing validated mortality estimates;

d) Conduct a meta-analysis, using the data detailed in 3, to improve the understanding of the explanatory variables associated with discard mortality and identifying potential mitigation measures; and

e) Based on ToR a) to d) a CRR should be developed for SCICOM consideration.

The first meeting was held on 17–21 February, 2014, at the ICES HQ in Copenhagen, to address ToR a).

Meeting Objective: Draft a set of concise guidelines on how to estimate discard survival rates, identifying useful examples and potential pitfalls, and where appropriate highlighting "best practice".

3. Participants and agenda

The meeting was attended by 23 people (2 by video link) and an additional 27 people have been working by correspondence (See Annex 2 and 3).

The agenda is attached as Annex 4

4. Drafting the Guidelines

All members of the workshop were asked to review and comment on the framework text drafted by STECF EWG 13–16 and a proposed outline for the ICES guidelines. The outline, the STECF text and associated comments formed the starting point for drafting of the guidelines. Task Groups (see below) were formed to review appropriate sections of STECF text, and associated comments, and draft the relevant sections of the guidelines based upon these and their own expert opinion.

5. The Task Groups

Task groups were assigned based upon individual experience and research interests (see Annex 4). Each task group leader coordinated the expertise within the task group to draft the guidelines, for that specific task, in response to the comments received on the STECF text, as well as the wider discussions of the WKMEDS members.

6. Meeting Organization.

The meeting opened with introductory presentations and discussions. Each of the following days bagan with a short plenary session, in which points can be raised for discussion and clarification. There were additional presentations scheduled to stimulate further discussion, particularly on planned survival assessments. Most of the week however was dedicated to writing the guidelines, within appointed Task Groups.

To monitor progress and highlight any issues for plenary discussion, there was a brief meeting at the end of each day with all of the task leaders, to summarize progress and raise points for discussion the next day.

During the group breakout sessions, the task groups were free to work on their tasks. Once a work-plan for each of the task groups had been agreed and specific tasks assigned, participants were encouraged to engage in discussions with the other task groups – to address specific issues or areas of mutual interest.

7. Important Dates & Deadlines

Date	Action	Responsible Persons
12/2/14	Provide comments on the STECF text	All members
17-21/2/14	WKMEDS Meeting I	Meeting attendees
28/2/14	Meeting Summary & Action List	Chairmen
17/3/14	Deadline for submitting draft text	Task Group members
21/3/14	Draft report circulated for review	Chairmen
31/3/14	Deadline for submission of comments on draft report.	All members
14/4/14	Submission of Final Report to ICES ACOM & SCICOM	Chairmen

8. References

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Annex 2: List of participants attending the meeting

Name	Address	Phone/Fax	Email
Mike Breen (Chair)	Institute of Marine Research P.O. Box 1870 Nordnes 5817 Bergen Norway	Phone +47 55 23 69 30	michaelb@imr.no
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Annex 4 Agenda

Monday 17th February - PM

1500 - Introduction

- Policy & Background – Tom Catchpole (CEFAS)
    - Discussion – Clarifying EU Requirements
- "What is discard mortality & how can we measure it?": building on the STECF framework – Mike Breen (IMR)
    - Discussion – Clarifying method & framework for defining guidelines

1630 – Brief description of forthcoming & ongoing survival projects

- Recent trials on flatfish survival using underwater cages – Bob van Marlen & Floor Quirijns (IMARES)
- Plans for discard survival studies in prioritized English fisheries – Tom Catchpole (CEFAS)
- Discard survival, the Canadian Perspective - Steve Cooke (Carleton University, Ottawa)
- Discard survival, the US Perspective - John Mandelman (New England Aquarium, Boston)

- Discussion

Tuesday 18th February

0900 - Plenary session

Brief description of forthcoming survival projects (Cont.)

- Nephrops survival study and proposal of a discarded fish survival assessment in the bay of Biscay – Sonia Mehault & Dorothee Kopp (IFREMER)
- Estimating of slipping mortality in purse-seine fisheries – Aud Vold (IMR)

Group Sessions – Focus on comments on specific task areas, plan redrafting

1400 – Towards an Integrated Approach

- Tagging Methods– Niels Jepsen (DTU-Aqua)
- Vitality Assessment – Hugues Benoit (Fisheries and Oceans Canada)

Group Sessions – Consider requirements for integration, continue with redrafting

Wednesday 19th February – AM

0900 - Plenary session

- RAMP & developing an integrated approach – Michael Davis
- Discussion on integrated approaches

Group Sessions – Consider requirements for integration, continue with redrafting

1400 - Plenary session

- Use & Abuse of Captivity Controls - Mike Breen (IMR)
- Discussion on use of controls

Group Sessions

Thursday 20th February

0900 - Plenary Session

- Plans for discard survival assessment in Skagerrak / Baltic - Thomas Noack (DTU Aqua)
- Survival experiments in the Basque purse-seine fleet - Luis Arregi (AZTI)
- Catch and release in European marine recreational fisheries and impacts on the fish - Keno Ferter (Bergen University)
- Estimating post-release cod survival in recreational fishery in the Western Baltic Sea – Harry Strehlow & Simon Weltersbach (TI-OF)
- Discard survival of trawled flatfish in the Baltic (A planned assessment) - Uwe Krumme & Harry Strehlow
- Project idea: Flounder survival trials in the Baltic Sea in Latvia - Didzis Ustups

Discussion: an integrated approach for planning and implementing survival assessments, using synergistic combinations of the different available methods, to promote accurate estimation of discard survival.

Group Sessions

Friday 21st February

0900 - Plenary Session

- Group Summaries
- Plan for completing the guidelines
- Assign tasks & deadlines

1330 – Meeting Close

Annex 5 Task Groups and contributors at the First Meeting of WKMEDS

0	INTEGRATED APPROACH DISCUSS AND DESCRIBE THE INTEGRATED PLANNING AND IMPLEMENTATION OF SURVIVAL ASSESSMENTS, USING SYNERGISTIC COMBINATIONS OF THE DIFFERENT AVAILABLE METHODS, TO PROMOTE ACCURATE ESTIMATION OF DISCARD SURVIVAL.	MIKE BREEN, TOM CATCHPOLE, HUGUES BENOÎT MICHAEL DAVIS, FLOOR QUIRIJNS, SEBASTIAN UHLMANN JOCHEN DEPESTELE
1	Explanatory Variables describe the selection and appropriate measurement of the likely explanatory variables influencing discard survival	Sebastian Uhlmann (Lead) Floor Quirijns Jochen Depestele Harry Strehlow Keno Ferter Simon Weltersbach Hans Nilsson Sonia Mehault
2	Captive Observation (Laboratory) (Merged with Task Group 3) describe the methods for observing the survival of test subjects in captivity in the laboratory, including the advantages and disadvantages of these approaches	Rolf Erik Olsen (Lead) Thomas Noack
3	Captive Observation (Field) (Merged with Task Group 2) describe the methods for observing the survival of test subjects in captivity during field studies, including the advantages and disadvantages of these approaches	Bob van Marlen (Lead) Aud Vold Jochen Depestele Harry Strehlow Keno Ferter Luis Arregi
4	Vitality Assessment describe the methods for estimating mortality indirectly from assessments of vitality (e.g. RAMP), including the advantages and disadvantages of these approaches	Michael Davis (Lead) Hugues Benoît Dorothee Kopp Jochen Depestele Simon Weltersbach
5	Tagging & Biotelemetry Assessment describe the methods for estimating survival using tagging and biotelemetry, including the advantages and disadvantages of these approaches	To be addressed in second meeting
6	Data Analysis Describe the most applicable statistical techniques for analysing binomial data, including consideration of experimental design (e.g. defining necessary sample size and replication).	To be addressed in second meeting

Annex 6 Draft ICES Guidelines on Methods for Estimating Discard Survival

An output from the WKMEDS meeting, Copenhagen, 17th to 21st February 2014

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Version 2.2

Editors

Mike Breen & Tom Catchpole

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