

CENTRE FOR ENVIRONMENT, FISHERIES AND
AQUACULTURE SCIENCE

SCIENCE SERIES TECHNICAL REPORT
Number 115

**MONITORING THE OUTCOME OF A SEASONAL
DREDGING RESTRICTION:
A PRECAUTIONARY APPROACH**

S.I. Rogers and M.D. Nicholson

LOWESTOFT
2002

This report should be cited as:

Rogers, S.I. and Nicholson, M.D. (2002). Monitoring the outcome of a seasonal dredging restriction: A precautionary approach. Sci. Ser. Tech. Rep., CEFAS Lowestoft, 115: 11pp

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SUMMARY

The need to monitor to show the success, or otherwise, of management measures is often overlooked. We show how fisheries monitoring is most effective when underpinned by a predetermined decision-making procedure which is related to meaningful scientific outcomes. The decisions which follow correspond to appropriate precautionary hypotheses, and they lead to adequate levels of sampling, unambiguous conclusions, and an agreed basis for decisions. This approach is applied to fisheries monitoring data from Hastings Shingle Bank to establish a protocol for assessing the effects on fish catches of a seasonal restriction on dredging.

1. BACKGROUND - GOVERNMENT POLICIES AND ADVICE CONCERNING THE EXTRACTION OF MINERALS FROM THE SEABED

When considering applications for marine dredging, and particularly applications in areas that are important for fish spawning, migration routes, or as nursery and over-wintering grounds, it is Government policy to adopt a precautionary approach (DTLR, 2001). The following text has been taken from the consultation draft of the Marine Minerals Guidance Note 1 (DTLR, 2001), which describes the UK Government's procedures, policies and advice on the extraction of minerals from the seabed in English territorial waters:

- 1). *'The Government will pursue a precautionary approach in the consideration of applications for marine minerals dredging.there will be a presumption against permitting new areas of extraction unless the issues relating to environmental and coastal impacts are satisfactorily resolved.'*
- 2). *'Particularly careful consideration will be given to proposals which might impact adversely on areas that areimportant for fish spawning, migration routes, or as nursery or over-wintering areas.'*
- 3). *'Where necessary, conditions will be imposed to restrict dredging activities at critical times of the year or states of the tide, in order to allow access by fishermen, or avoid disturbance of fisheries. The effectiveness of such restrictions should be monitored and should be carefully considered when the monitoring results are periodically reviewed.'*
- 4). *'Monitoring operations are expensive, as they require considerable resources both at sea and in subsequent sample and data processing. It is important, therefore, to ensure that a monitoring programme is*

properly designed so that it meets its objectives. The results should be reviewed at regular intervals against the stated objectives and the exercise should then be continued, revised or terminated.'

This Technical Report discusses one approach to developing a monitoring programme with clearly defined objectives that conforms to these precautionary ideals. Section 2 reviews the current scientific information concerning trends in sole catches at Hastings. Sections 3-6 consider the problems of both agreeing the objectives of monitoring and designing an effective, scientifically-based programme. Section 7 gives a simple example of what this might look like in practice.

2. BACKGROUND – THE SOLE FISHERY AT HASTINGS SHINGLE BANK

The fixed net fishery for sole inshore of the Hastings Shingle Bank has traditionally been one of the most important UK fisheries in the Eastern Channel, but a decline in catches since the late 1980s has led to local fishermen considering the fishery to be less economically viable than it once was. The occurrence of regionally important deposits of aggregate at Hastings Shingle Bank has led fishermen to believe that the decline in catches is related to this activity. Comparison of fish landings and extraction rates of aggregate has not demonstrated any direct relationship. A monitoring programme which compared catches at traditional fishing grounds and at a nearby control site provided no evidence of a spatial difference. Analysis of trends in commercial landings at Hastings and ports to the east and west suggested, however, that only Hastings and one neighbouring port, Eastbourne, had undergone a consistent decline in catches.

Although there is no evidence that dredging at Hastings is directly responsible for the decline in sole catches, the continuing decline in landings at Hastings, but not at similar ports in the area, is a concern, and suggests a precautionary approach. In keeping with paragraph 3) quoted in Section 1, one strategy might be to restrict aggregate extraction during the spring fishing period, on the assumption that aggregate removal may be impeding the onshore migration of fish. The most appropriate period would be from mid-February to the end of April when sole move inshore to spawn, a restriction of 10 weeks. However, for the strategy to be complete, it must be accompanied by a monitoring programme with clearly defined objectives as described in the Guidance, quoted in section 1. This Technical Report considers formal ways in which this programme can be *"...continued, revised or terminated."*

3. THE PROBLEM

Assume that a fishery is in decline, and the objective is to restore current catches to a previous, more favourable level (referred to as the *status quo*).

If a seasonal restriction is imposed, it will be necessary to review its effectiveness at regular intervals. Clearly there is no value in applying a mitigation measure that does not achieve its intended purpose. But how should the response to the restriction be evaluated, and what decisions should be made about lifting the restriction?

If after implementation of the restriction the sole catches remain the same or continue their steady decline, the fishermen may press for a longer restriction on the assumption that the original was not effective. On the other hand, the aggregate industry will want it removed on the grounds that it has been ineffective. If catches increase, it will be assumed that the restriction was effective. The fishermen may then argue for it to be sustained, since the inverse-relationship between dredging and catches has been demonstrated. The aggregate industry could argue for the restriction to be lifted, since it is now unnecessary.

The basis for these disputes could be removed if there is a clear understanding of the basis for future decisions, identified and agreed before the restriction and the monitoring begin. At its simplest, this agreement may only exist at the scientific level with clear monitoring objectives and an appropriate level of sampling. But the benefits would be even greater if such agreements included policy makers and both the fishing and dredging industries.

4. FROM THE FISHERMEN'S PERSPECTIVE - PRECAUTIONARY HYPOTHESES

In statistical tests, the traditional null hypothesis is that there has been no effect (e.g. of dredging). For example, writing μ for the mean CPUE of sole at Hastings we could have:

$$H_0 : \text{no effect.} \quad \text{i.e. } \mu = \textit{Status quo.}$$

If this null hypothesis is rejected, we might accept the alternative hypothesis:

$$H_1 : \mu < \textit{Status quo.}$$

If after the dredging restriction was applied there was no significant difference between seasonal fish catches and

the *Status quo* catch (i.e. the pre-dredging level of fish catch), it may be because there really was no effect to be seen, or it may be because there was an effect but the test had insufficient statistical power to find it. These hypotheses are decidedly un-precautionary. The burden of proof is on the fishermen to establish that catches are less than the *Status quo*. If they fail, the *Status quo* is assumed to apply.

One route to a precautionary approach is to reverse the roles of these hypotheses and agree an acceptable level of impact. The null hypothesis is then that the impact is worse than this agreed level. If a small reduction in *Status quo* catches (e.g. less than 20%) is acceptable, then the monitoring programme has to show that the catches are significantly better than this, i.e. they fall within Zone A of Figure 1. The position of the lower boundary of Zone A depends upon the chosen statistical test, and corresponds to the critical value for choosing between:

$$\begin{aligned} H_0 : \mu &\leq 0.8 \times \textit{Status quo} \\ &\text{vs} \\ H_1 : \mu &> 0.8 \times \textit{Status quo.} \end{aligned}$$

The burden of proof has now been reversed, reflecting the precautionary assumption that dredging could be having an effect.

5. FROM THE AGGREGATE EXTRACTION PERSPECTIVE – EVIDENCE OF NO-CHANGE

A similar set of hypotheses can be defined to test whether or not the control measures have failed to improve the catch. In this case the procedure is reversed. Suppose there is an agreed recovery in catch rates that is considered to be the minimum that is worthwhile (e.g. greater than 20%). If, at some future date, recovery was significantly less than 20%, then we would conclude that the restriction had had no effect. i.e. catch rates tend to fall in Zone C of Figure 1 corresponding to a test of :

$$\begin{aligned} H_2 : \mu &\geq 1.2 \times \textit{Current Catch} \\ &\text{vs} \\ H_3 : \mu &< 1.2 \times \textit{Current Catch.} \end{aligned}$$

These hypotheses are again precautionary, and place the burden of proof on monitoring to demonstrate that the small change in catches was significantly less than 20%, and within Zone C of Figure 1.

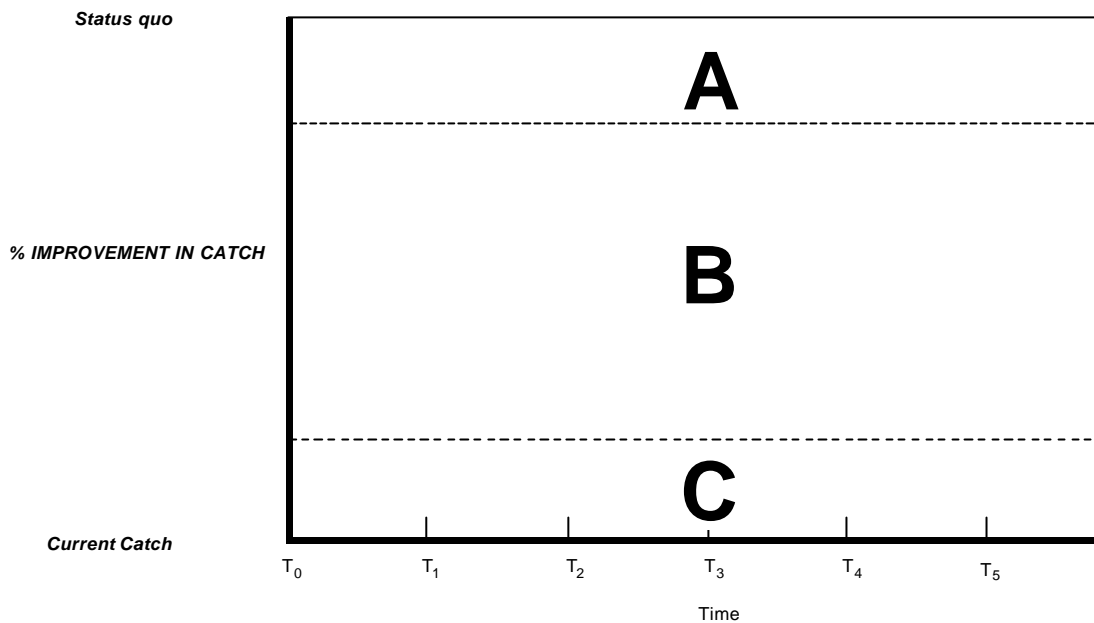


Figure 1. A schematic figure showing a method of evaluating precautionary hypotheses. If a certain reduction from a previously favourable (Status quo) catch is acceptable, then the monitoring programme must show that the catch is significantly better than this (i.e. in Zone A). To test whether or not the management measures have failed to improve the current catch, the procedure is reversed. If at some future date the catch was significantly less than the agreed level of worthwhile improvement, then we would conclude that the ban had had no effect (i.e in Zone C). Catches in Zone B suggest that there may be an improvement

6. RELATING DECISIONS TO HYPOTHESES

So far, no actions or decisions have been associated with the various hypotheses described above. These will be based on the best scientific understanding of the fishery, and may call for specific actions, such as further monitoring or a review. For example, for those catch rates which fall within Zone A (fishery

improved), the dredging restriction may have been effective and should be maintained, but monitoring should eventually be reduced to a ‘watch-dog’ level to protect against further reduction. Catch rates which fall consistently within Zone B suggest that the fishery may be improving, and that monitoring should continue. In Zone C (no improvement) the dredging restriction has had no effect and other mitigation measures should be evaluated (Table 1).

Table 1. Actions and decisions that may be associated with the hypotheses described in Sections 4 and 5

Figure 1 Zone	H_0 versus H_1	H_2 versus H_3	Value of μ	Possible Conclusion/Decision
A	significant	not tested	$\mu > 0.8 \times \text{Status quo}$	Fishery improved - restriction may have been effective; Maintain 10 week restriction; Continue monitoring to protect against renewed decline, but eventually reduce level to ‘watch-dog’ status to protect against further reduction.
B	not significant	not significant	$1.2 \times \text{Current Catch} \leq \mu \leq 0.8 \times \text{Status quo}$	Fishery may be improving; Maintain 10 week restriction. Continue monitoring.
C	not significant	significant	$\mu < 1.2 \times \text{Current Catch}$	Fishery not improving – restriction has no effect; End 10 week restriction; Evaluate other mitigation measures and consider other causes of decline. Continue monitoring.

7. PUTTING IT TOGETHER – EVALUATING THE EFFECT OF A RESTRICTION AT HASTINGS SHINGLE BANK

7.1 Setting appropriate targets

The following example demonstrates how this might work in practice. The catch thresholds used are merely chosen for illustration. In order to test these hypotheses, there will need to be a statistically designed monitoring programme with a corresponding set of statistical tests of significance. The programme and the tests are chosen so that the risks of reaching a wrong decision are acceptably small. The following simple example demonstrates how this might work.

There is an existing monitoring programme at Hastings which provides detailed spatial catch per unit effort data for a representative portion of the fleet, and which can be used to monitor future changes in the fishery. To be useful, it is necessary to identify *Status quo* catch rates based on our knowledge of historic, pre-dredging catches at local ports. The average sole landings per boat in kg day⁻¹ for the months March-July for the Pre-dredging period (1984-1988) and the Current period (1994-2000) are given in Table 2. These correspond to the DEFRA fisheries statistics for Brighton and Newhaven, and Hastings and Eastbourne, and to the monitoring data at Hastings.

Since there was no monitoring at Hastings during the pre-dredging period, the pre-dredge monitoring catch of 55.3 kg day⁻¹ at Hastings has been estimated *pro-rata* to maintain the relative catch rates between the three data series.

Hence this figure represents the *Status quo* relative to Brighton and Newhaven that fishermen would like to see restored. This is equivalent to a ratio of approximately 1.92 between the catches in the Hastings monitoring programme and the commercial landings data from Brighton and Newhaven.

The current catches in the Hastings monitoring programme of 21.5 relative to 22.8 kg day⁻¹ elsewhere, is equivalent to a ratio of 0.94.

Suppose that an agreed target catch rate for the upper threshold (i.e. within Zone A of Figure 1) would occur when it is significantly better than 0.8 x *Status quo*, and that an acceptable risk of wrongly concluding that the catch rate is more than 0.8 x *Status quo* is 1%.

Similarly, suppose that any recovery to a catch rate significantly less than 1.2 x Current Catch would not be considered worthwhile in terms of the effectiveness of the restriction. Also, suppose that an acceptable risk of wrongly concluding that the catch rate is less than 1.2 x Current Catch is also 1%.

In this example, the same level of risk has been selected for wrongly concluding that the restriction was having no worthwhile effect. Setting a lower risk for this threshold would lead more quickly to seeking other causes of stock decline.

7.1.1 Decision rules

Assuming that the current monitoring programme continues, the final step is to define appropriate statistical tests so that there is at most a risk of 1% of rejecting;

$$H_0 : \mu \leq 0.8 \times \textit{Status quo}$$

in favour of

$$H_1 : \mu > 0.8 \times \textit{Status quo} \quad \text{when } H_0 \text{ is true,}$$

and that there is at most a risk of 1% of rejecting;

$$H_2 : 0.8 \times \textit{Status quo} \geq \mu \geq 1.2 \times \textit{Current Catch}$$

in favour of

$$H_3 : \mu < 1.2 \times \textit{Current Catch} \quad \text{when } H_2 \text{ is true.}$$

Table 2. Sole landings data for ports on the south coast

Period	DEFRA Fisheries Statistics		Monitoring data
	Brighton & Newhaven	Hastings & Eastbourne	Hastings
Pre-dredging	28.9	46.5	(55.3)
Current	22.8	18.1	21.5

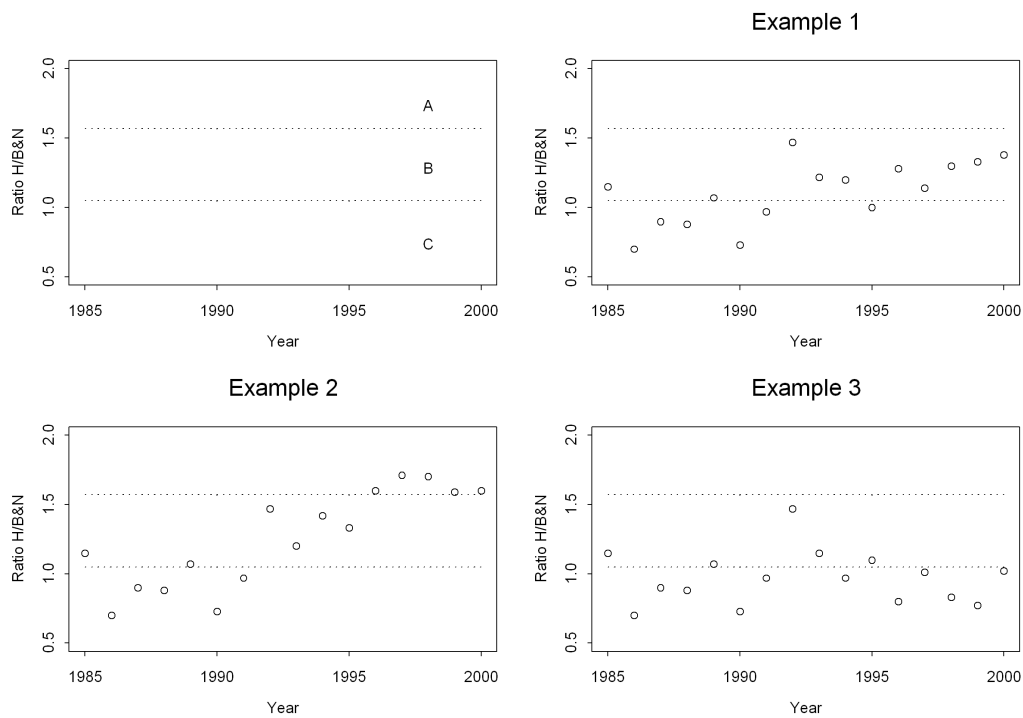


Figure 2. Three examples of possible scenarios showing how different patterns of monitoring results would lead to different decisions

7.1.2 Simple statistical tests for making decisions

There are many statistical procedures that could be adopted. Consider the following simple tests based on the minimum and maximum annual ratios calculated from the most recent 5 years – labelled Min_5 and Max_5 respectively. Then using the historic data and making some sensible statistical assumptions, it is easy to construct the following series of decision rules:

- if $Min_5 > 1.57$: accept H_1 (improved)
- if $Min_5 \leq 1.57$ and $Max_5 \geq 1.11$: accept H_2 (may be improving)
- if $Max_5 < 1.11$: accept H_3 (no improvement)

The first graph in Figure 2 shows these test reference points with the three areas designated A, B and C, as described before in Figure 1. The next three figures present possible scenarios showing how different patterns of monitoring results would lead to different decisions. In Figure 2, Example 1, there is some suggestion of increasing catch ratios monitored at Hastings to those observed at Brighton and Newhaven. However, by the year 2000 it has not demonstrated a statistically significant improvement. Example 2 shows the ratio increasing steadily from 1985 to 2000, at which stage the test would conclude that a statistically significant

recovery had been made (i.e. 5 successive years with a ratio greater than 1.57). In Example 3, the conclusion at year 2000 would be that there is no evidence of recovery, and that the restriction has had no discernible effect.

8. ASSESSING THE PERFORMANCE OF THE MONITORING SCHEME

How effective will the monitoring scheme be? This can be assessed by calculating the probabilities that particular decisions will be made. These probabilities will, of course, depend on what is the true value of the relative catch rate between Hastings, and Brighton and Newhaven. Figures 3(a) and (b) show these probabilities as a function of the true relative catch rate for the following outcomes and decisions as described in Section 7.

Outcome	Decision
$Min_5 > 1.57$	accept H_1 (improvement)
$Max_5 < 1.11$	accept H_3 (no improvement)

To show the effect of basing decisions on information from different numbers of years, the probabilities have been constructed assuming that a test will be made using the most recent 3 or 5 years as described in Section 7.

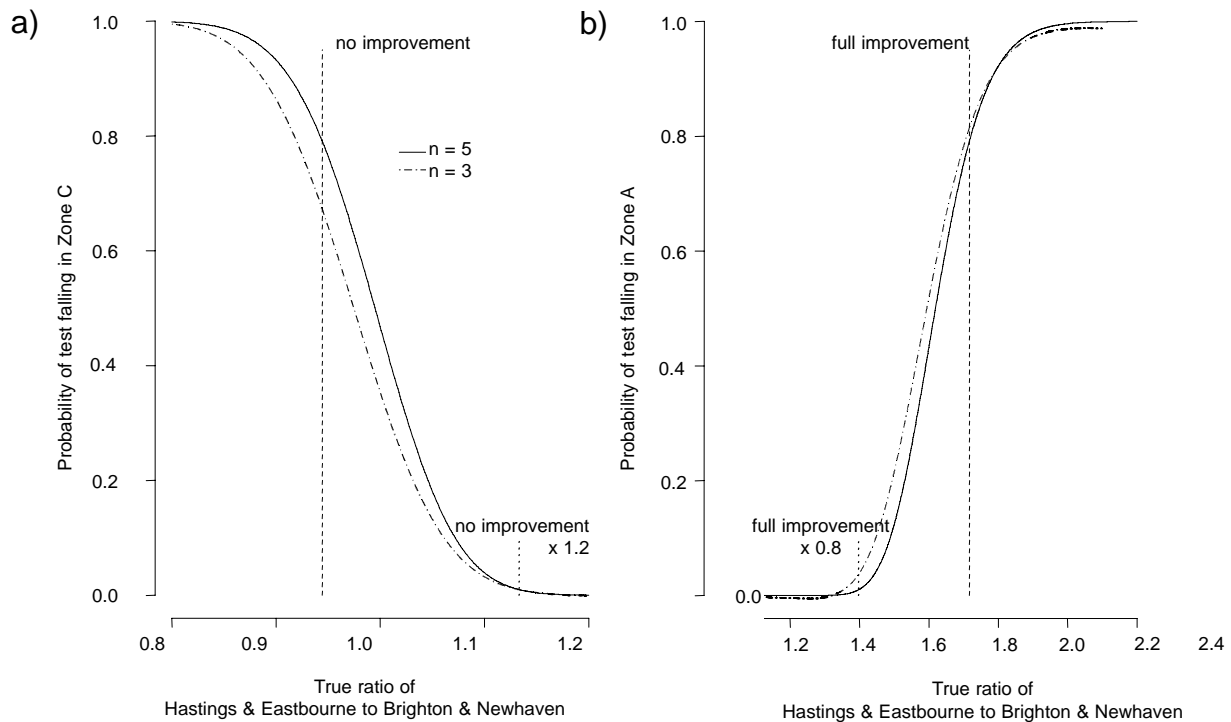


Figure 3. The probability of concluding that the mitigation measure had produced no worthwhile improvement (Figure 3a) and had resulted in a significant improvement (Figure 3b), assuming test periods of 3 and 5 years

In Figure 3(a), a vertical reference line has been drawn at $true\ mean = 1.2 \times Current\ Catch$, for which the probability was set at 1% by design. A second line has been drawn at $true\ mean = Current\ Catch$ ('no improvement'), for which the achieved probability of concluding that there has been no improvement is approximately 80% with $n = 5$ years, and 67% with $n = 3$ years.

Figure 3(b) shows a similar plot corresponding to the probability of concluding that there has been an improvement of the fishery at Hastings and Eastbourne relative to Brighton and Newhaven. In this case, a vertical reference line has been drawn at $true\ mean = 0.8 \times Status\ quo\ Catch$, for which the probability was again set at 1% by design. A second line has been drawn at $true\ mean = Status\ quo\ Catch$ ('full improvement'), for which the achieved probability of concluding that there has been full improvement is again approximately 80% with $n = 5$ years, and 67% with $n = 3$ years.

The performance of the monitoring programme will also depend on the statistical test used. The test used for demonstration here has both bad and good points. The disadvantages are that it is relatively inefficient,

and its power does not increase with the number of monitoring years. However, the principles are the same for any test, and a more-efficient test could be developed. The advantages of this test are that it is simple to apply and to interpret visually, and it makes no assumptions about any pattern of temporal change.

9. DISCUSSION

The theoretical results presented above show how a precautionary approach might be incorporated in a monitoring programme which includes appropriate hypotheses and statistical tests. In this example, the short-term precautionary objective for sole catch rates at Hastings is to apply a restriction on dredging in the hope that the fishery can regain relative parity with catch rates at nearby ports. The statistical procedure has been chosen to reflect this objective, but has been extended to provide a test of an additional outcome – that the restriction has had no effect. Although the procedure is simple to apply, choosing the values of the tolerable reduction in the *Status quo* and a not-worthwhile increase in the *Current Catch* may be difficult. Similarly, what level should be set for the risks of wrongly rejecting the null hypotheses?

In any monitoring programme, however, values for these quantities are implicitly included in the design of the programme, and characterise its performance. Making them explicit is more likely to result in a sensible balance of management and scientific objectives. For example, accepting a lower risk of concluding that the restriction was having no worthwhile effect would lead more quickly to investigating other forms of management.

Similarly, basing the test on the maximum or minimum catch in a five year period might also be judged meaningful in terms of the known biological characteristics of the stock. There are other tests that could have been chosen, and other test statistics. For example, a test could be based on the average or median catch, which may be less stringent than requiring that every annual index in a given period complies with some reference value.

However, these issues are mostly about the choice of procedure. The essential difference with this approach is making these choices explicit, and to reverse the burden of proof from showing an impact (unprecautionary) to showing an acceptable level of impact (precautionary).

10. REFERENCE

DTLR, 2002. Draft Marine Minerals Guidance Note 1: Guidance on the Extraction by Dredging of Sand, Gravel and other minerals from the English Seabed. Consultation Paper. Department of the Environment, Transport Local Government and the Regions, London. April 2002. 26pp.