Ballast Water Management Decision Support System

Matej David and Stephan Gollasch

Abstract A Decision Support System (DSS) is a supporting tool enhancing a decision-making process. Decision-makers are frequently faced with the problem to take decisions on very complex issues, which requires large data inputs, and a timely decision process. DSSs provide decision makers with a tool to reduce uncertainties, and to simplify and speed-up the decision process as well as to avoid subjectivism induced by the decision-maker and to guarantee transparency of a decision process. The DSS approach has been introduced in the ballast water management (BWM) field and the need primarily arose with the introduction of the selective BWM approach. More precisely, it was recognised that a supporting tool is needed to aid transparency and consistency when deciding on BWM requirements to achieve better environmental protection and lessen burden on vessels. The DSS process starts with communication and data input, continues with risk assessment, BWM decisions, vessel's action(s), and ends with monitoring and review processes. Throughout the entire decision process information needs to be exchanged with outer (e.g., vessel, other ports) and inner sources (e.g., vessel's particulars, compliance history), and therefore needs to be supported by adequate communication processes and data management. When required BWM measures were not conducted properly the BWM DSS endpoints range from situations where unmanaged ballast water can be discharged to cases where vessels may be turned away. The chapter provides a detailed step-by-step DSS model which may be used by administrations and other authorities involved in the decision making processes.

Keywords Decision support system • Ballast water management • Port State control • Port State authority • Risk assessment • Ballast water management convention • Harmful aquatic organisms and pathogens

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What Is a Decision Support System

A Decision Support System (DSS) is a supporting tool enhancing a decision-making process (Bhatt and Zaveri 2002). DSSs use a combination of models, analytical techniques, and information retrieval to help developing and evaluating appropriate decision alternatives (Adelman 1992; Sprague and Carlson 1982; Sojda 2007). Today DSSs are widely used to support decision-making processes in business, social sciences, medicine, politics, games, information technologies, transport (Marquez and Blanchar 2006), and they are major components in environmental management and science (Denzer 2005).

Decision-makers are frequently faced with the problem to take decisions on very complex issues, which requires large data inputs, and a timely decision process. DSSs provide decision makers with a tool to reduce uncertainties (Graham and Jones 1988), and to simplify and speed-up the decision process.

Decision Process and Decision Support System

One of the critical factors in the decision making process is subjectivism induced by the decision-maker (Paradice 2006). Decisions are influenced by subjectivity mostly because different decision-makers have varying levels and different background, knowledge, skills, moods, etc. The use of a DSS from this point of view is important, because, by principle, it eliminates subjectivity impacts of different decision-makers in the same process, which leads to more consistent results – i.e., decisions. It also ensures consistency of decisions taken by the same decision-maker. However, the DSS is exposed to subjectivity during the preparation/construction process. The results of a decision-making process may further be influenced (sometimes this is almost anticipated) by the authorities that order a DSS, i.e., they would like to achieve a certain result of their interest.

Another critical point is the transparency of a decision process. DSS should be constructed in such a way that decision models as well as decision steps are transparent, thereby enabling a review of the decision process at any time in the future. This is especially critical when a DSS is used in a regulatory framework.

Any errors possibly resulting from a decision process should also be known. Errors could occur in view of exactness and accuracy. Exactness means that a step of the process, or the process itself, in certain instances (e.g., lack of data, reliability of data, precision of data, subjective impacts), could produce a biased (false) result. Accuracy means that the result of a step in the decision process, or the process itself, may have a certain discrepancy or deviation as a consequence of certain instances (e.g., lack of data, reliability of data, exactness of data, subjective impacts). Hence, the DSS should produce exact answers with an acceptable accuracy.

Decision Support System Generic Structure

DSSs may have different elements and structures depending on their field of application and complexity (Denzer 2005). However, their very generic framework may be similar in different fields of application and generally contains decisions and data management. Decisions comprise of management decision steps and decision models (see Fig. 1) which represent the core elements of the DSS. The data management as component of a DSS comprises databases for data retrieval and data storage.

The integration of basic DSS elements is important for the preparation of a computer support architecture (Denzer 2005). As an example, the focus/application of a DSS may use different methodologies supporting the decision making process as, e.g., multicriteria decision making (e.g., Vincke 1993), fuzzy logic (e.g., Ru and Eloff 1996; Ekel 2002; David and Malej 2002), neural networks, etc. Once a computer model for a DSS process is prepared, this may also be used, with some adaptations, for another similar application and hence facilitate the development of a new DSS.

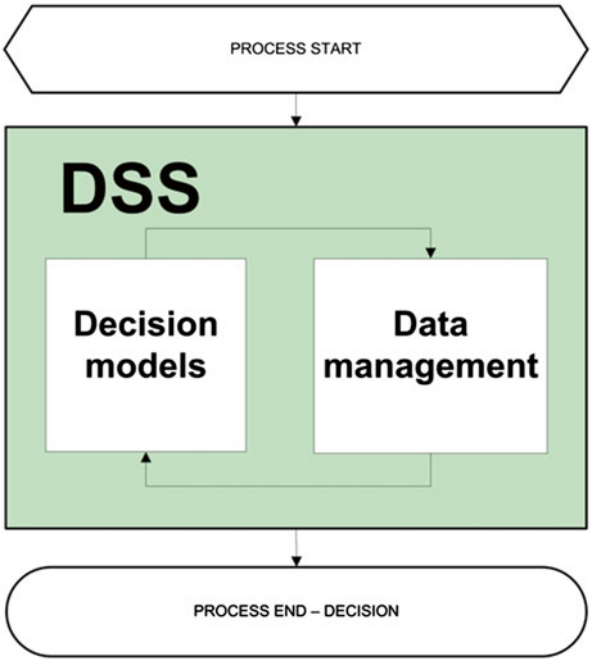

Fig. 1 Basic structure of a decision support system (DSS) showing how decision models and data management are related

Decision Support System in Ballast Water Management

The DSS approach has been introduced in the ballast water management (BWM) field and its need primarily arose with the introduction of the selective BWM approach. More precisely, it is a supporting tool needed to aid transparency and consistency when deciding on most efficient BWM requirements, and to lessen the burden on vessels (David 2007).

There are two different basic selective approaches in BWM, i.e., the "risk assessment (RA) approach" and "compliance history approach".

The RA approach is when the decision on BWM requirements relies purely on results from a scientifically based RA. For instance, a vessel which sails to a port where it needs to discharge ballast water, may be exempted from BWM requirements if the ballast water does not pose a risk or is of an acceptable level of risk to a recipient port. However, if the ballast water is found to be of (very) high risk, different additional measures may be introduced as a protective BWM measure. The RA approach could be either based on environmental matching, be species specific or use biogeographical aspects (see chapter "Risk Assessment in Ballast Water Management").

The compliance history approach relies on the documentation of vessels compliance or non-compliance with requested BWM practices, which is very much the regular practice of Port State Control (PSC) inspections. Vessels may not be in compliance with BWM requirements for different reason (e.g., technical failure, bad weather). However, the critical issue is that compliance monitoring in the first place is based on the declaration of responsible crew members (i.e., when ballast water exchange (BWE) is an implemented BWM method) or it is based on certificates (i.e., when the use of ballast water management systems (BWMS) is an implemented BWM method). This means that a compliance history needs to include vessels non-compliance records and responsible persons' false reporting history (i.e., trustworthiness) (Chad Hewitt pers. comm.). In cases of non-compliance and relative to the reason (e.g., history of technical failure may be treated less critical than false reporting of a responsible person), more attention may be paid to such vessels to ensure compliance, e.g., conduct PSC inspection on such vessels, or BWM measures may be even more stringent because of limited or no trustworthiness.

The result of RA is the level of risk posed to the ballast water receiving environment. According to this result, a decision on what to do is given by the DSS and followed by appropriate BWM preventive action. Monitoring of compliance with the implemented BWM regime (i.e., requested actions) is essential. Further, monitoring of compliance, as well as the DSS effectiveness, also needs to be conducted. If necessary, corrective actions are to be taken (see Fig. 2).

While the RA result is a simple answer in terms of the level of risk, in the following steps a more complex process is generated when a decision on "what to do" has to be taken considering the RA result, vessel trustworthiness, adequate and feasible BWM options, etc. DSS is the core part or, in other words, is the brain of the whole process.

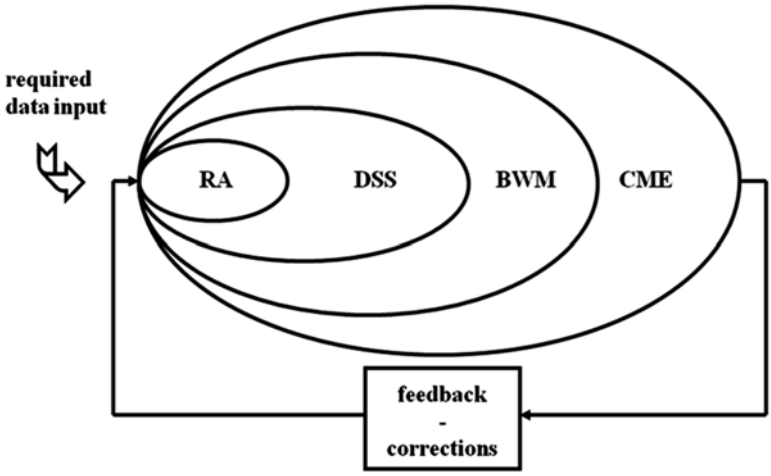

Fig. 2 The BWM process under the selective approach supported by the DSS (Enhanced after David 2007). *BWM* Ballast Water Management, *CME* Compliance Monitoring and Enforcement, *RA* Risk Assessment

Ballast Water Management Decision Support System Model

Model High Level Elements and Sequences

The DSS process starts with communication and data input, continues with RA, BWM decisions, vessel's action(s), and ends with a monitoring and review processes. Throughout the entire decision process information needs to be exchanged with outer (e.g., vessel, other ports) and inner sources (e.g., vessel's particulars, compliance history), and therefore needs to be supported by adequate communication processes and data management (see Fig. 3).

One of the critical issues is the position/situation/location of the vessels in relation to its ability to comply with requested BWM measures. In this regard we created four situations a vessel may be facing:

Situation (1), the vessel has left the last port of call and is able to conduct BWM on its intended route, and:

- has time and is in conditions to conduct the requested BWM measure(s);
- conducts BWM measures according to the requirements and enters the port with the permission to discharge ballast water.

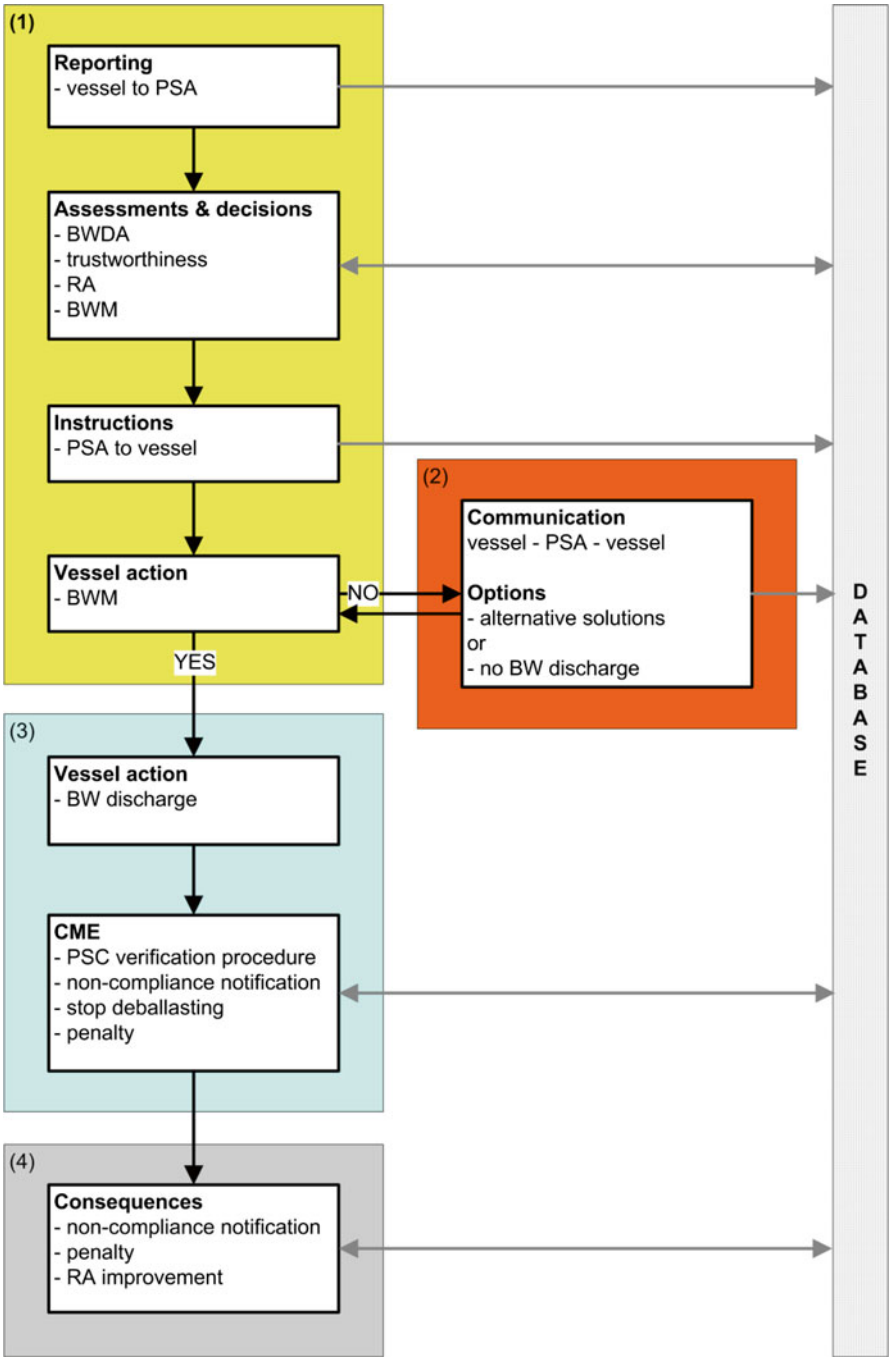

Fig. 3 DSS model high level elements (Enhanced after David 2007). *BW* Ballast Water, *BWDA* Ballast Water Discharge Assessment, *PSA* Port State Authority, *PSC* Port State Control. *Yellow box* is Situation (1) – vessel is on the way to port of call, BWM enabled; *orange box* is Situation (2) – vessel is on the way to port of call or even entered the port, no BWM enabled and the port entry permit is not yet issued; *light blue box* is Situation (3) – vessel is in the port, the port entry permit is issued; and *grey box* is Situation (4) – vessel has left port of call

Situation (2), the vessel has left the last port of call but is not able to conduct BWM on its intended route, and may already be in the port of arrival but the port entry permit[1] is not yet issued, and:

- did not use the BWMS;
- did not conduct BWM, but complies with the requirements (when the D-1 standard is required) because on its intended route the vessel does not exit the 50 nautical miles from nearest land and 200 m water depth limits to enable a BWE, nor it crosses a ballast water exchange area (BWEA);
- did not conduct BWM for other reasons;
- is deviated from its intended route to the BWEA and/or slowed down to conduct BWE and complies with the requirements;
- would need to be sent outside the 50 nautical miles and 200 m limits, or to a BWEA at a substantial change of her intended route, or use an alternative solution[2] to conduct BWM and comply with the requirements;
- depending on the RA result, may be allowed to discharge unmanaged ballast water,
- may be penalized, or
- may not be allowed to discharge ballast water without BWM.

Situation (3), the vessel is in the port of arrival and has received the port entry permit, and:

- may be targeted for different levels of compliance control;
- if the vessel is found non-compliant with BWM requirements, depending on the RA result, she may be allowed to discharge unmanaged ballast water, may be penalized, or may not be allowed to discharge unmanaged ballast water.

Situation (4), the vessel has received clearance[3] and left the port, and:

- the vessel's ballast water was sampled and was identified as non-compliant with BWM requirements, this is communicated to the vessel, the vessel's administration, the recognized organization responsible for the issue of certificates, and the next port of call; or
- the vessel's ballast water was sampled and was identified as compliant with BWM requirements, no action is required.

The high level elements with the four different vessel's situations are presented in Fig. 3.

The DSS integrates seven basic elements:

- data collection and management process;
- communication processes;
- ballast water RA process;

[1] Permit to start operations in a port, including anchorage, after having complied with port State requirements and submitted all required documents for port entry.

[2] e.g., alternative ballast water discharge area, port reception facilities.

[3] Permit to leave the port after having complied with port State requirements and submitted all required documents for leaving the port.

– BWM decision and action process;
– BWM action process;
– compliance monitoring process; and
– RA review process.

Each of these elements has its own function and the DSS structure provides for their effective integration, and supports their independent functioning as well as their mutual interrelations.

Data Collection and Management Process

The data collection process is critical simply because decisions are based on these; i.e., wrong data input would result in a wrong answer. This mostly relies on port States, as the BMW Convention does not provide requirements for reporting from vessels to ports regarding ballast water operations, but only requires an on board BWM log book. In this context two main aspects need to be considered: data availability; and data reliability.

Regarding data availability, correct data need to be available at the right time. This means all data needed for the whole process to enable taking all decisions are essential; e.g., biological data on ballast water source ports, environmental data from source and receiving ports, vessels data on previous reporting. It is important that the data are available timely to allow the vessel to conduct the requested BWM practice; i.e., time to conduct RA, take a decision on BWM requirements, communicate with vessel, conduct BWM or take appropriate action.

Data reliability has quality and quantity aspects. The quality of data in the first place means that the DSS input data are based on reliable sources. In terms of quantity, there should be enough comprehensive data to be statistically robust.

Most of the data received externally as well that from the decision process need to be managed properly, be safely stored and accessible, which may be best arranged in a DSS database. This database provides the DSS with the information needed, e.g., vessels particulars, historical data on vessels compliance, as well as it is serving the needs of outer sources; e.g., sharing information with other stakeholders, reviewing the DSS process and as back-up for a later review process of a single decision.

Communication Processes

The communication process consists of communications among the port State authority (PSA) and:

– the vessel;
– the vessel's administration;
– the vessel's recognized organization responsible for the issue of certificates

– the vessel's next port of call; and
– IMO.

The essentially needed communication regarding BWM is established between PSA in the ballast water recipient port and the vessel that intends to discharge ballast water as follows:

– the vessel intending to discharge ballast water submits requested information as ballast water reporting form (BWRF) to the PSA;
– PSA communicates to the vessel the decision on BWM requirements;
– other communication, e.g., in case the BWRF was not satisfactory completed or the vessel was not able to conduct the required BWM.

In case a vessel would be found non-compliant with the BWM Convention, PSA that established this, needs to communicate it to the related vessel, the vessel's Administration, the vessel's next port of call and the recognized organization responsible for the issue of certificates. Should additional BWM measures be introduced in a known epidemic or emergency situation, PSA needs to communicate this to all vessels in the area(s) under their jurisdiction where vessels should not uptake ballast water, and the ballast water uptake avoidance area(s) need to be communicated also to IMO.

The preferred communication pathway may be via electronic means, fully or partially automated, e.g., via internet application, email, fax, telex, vessels agent, telephone. Non-automated means of submitting information, i.e., on paper forms, are considered as impractical since the information would not be exchanged and implemented into DSS in a timely manner.

Ballast Water Risk Assessment

The RA forms a core part of DSS triggering different decisions regarding:

– BWM practice needed;
– compliance monitoring needs; and
– the level of inspection.

In the RA based DSS, the decisions on BWM practices mostly[4] rely on the results of the RA, e.g., high/extreme risk – the vessel must conduct BWM, medium risk – should conduct BWM, low risk – may conduct BWM. The RA results are further critical for taking decisions regarding compliance monitoring; i.e., targeting vessels for inspection, as well as taking decisions on the level of inspection, i.e., paper checks, indicative BWS, detailed BWS.

[4] Decision on the need for BWM practice may rely also on trustworthiness, *i.e.*, compliance history of a vessel, master or responsible officer.

Ballast Water Management Decision and Action

Management decisions in this context are required BWM practices which are selected on the basis of the RA result, vessels trustworthiness, and if the BWM measures have already been undertaken the acceptability of these. Based on the RA result and vessel's trustworthiness, the vessel may also be exempted from undertaking BWM, or may be exposed to additional measures according to the level of risk assessed. Such additional measures include to conduct BWE, deviate from its intended route or slow down to conduct full BWE, treat ballast water with active substances before discharge, discharge ballast water to a reception facility, or do not discharge unmanaged ballast water.

Compliance Monitoring

Compliance monitoring is a process needed to back-up the port State requirements. It is focused on the adequate and effective implementation of the requested BWM practices. This process may be triggered by suspected false ballast water reporting (e.g., ballast water discharge assessment (BWDA) result, vessels and/or crews trustworthiness), by suspected non-compliance, by RA (e.g., when high/extreme risk ballast water is to be discharged), or by random vessel selection as part of the regular inspections process. A vessel selected for compliance monitoring will be inspected, and if non-compliant the ballast water operation may have to be stopped, and the vessel may be penalized.

Risk Assessment Review Process

A review process needs to be implemented which is critical for further improvements of the BWM DSS process and results. The review process includes a reassessment of the RA procedure based on ballast water sampling results.

Generic Ballast Water Management Decision Support System Model

The BWM DSS process starts with the vessel submitting the required data to enter the port, and through the RA and BWM ends with the monitoring process and, if necessary, result in corrective actions of the process. Throughout the entire process is a dynamic flow of information exchange supported by adequate communication processes and data management. Considering that there are a lot of different situations and issues (e.g., non-adequate or false reporting, non-ability to comply with required BWM practice, technical issues) that may arise during each vessel call to a port, the BWM DSS model was prepared to cover possibly all predictable events, as well to respond rapidly. The generic model is presented in the Fig. 4, followed by

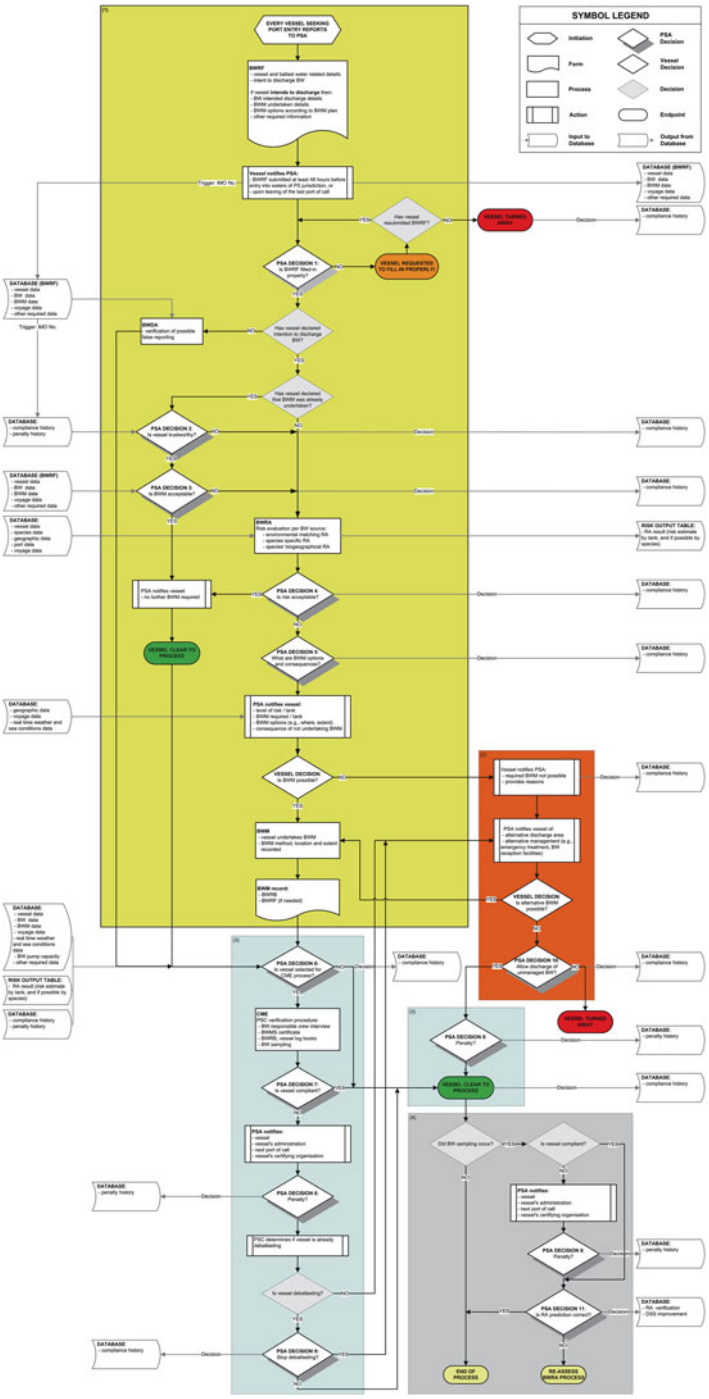

Fig. 4 BWM DSS generic model (Enhanced after David 2007). The *yellow box* is Situation (1) – vessel is on the way to port of call, BWM enabled); *orange box* is Situation (2) – vessel is on the way to port of call or even entered the port, no BWM enabled and the port entry permit is not yet issued; *light blue box* is Situation (3) – vessel is in the port, the port entry permit is issued; and *grey box* is Situation (4) – vessel has left the port (*BWRA* Ballast Water Risk Assessment, *BWRB* Ballast Water Record Book, *BWRF* ballast water reporting form) (This figure can be downloaded from http://extras.springer.com/)

the presentation and description of all BWM DSS elements in sequence. The BWM DSS was also applied to a real world scenario taking the Port of Koper, Slovenia, as an example (see chapter "Ballast Water Management Decision Support System Model Application").

Vessel Intended to Enter a Port

Each vessel seeking a port entry permit has to submit ballast water information requested by the PSA. This can be done via BWRF or electronic means, depending on PSA requirements. To implement selective BWM supported by BWM DSS, ballast water reporting in advance is crucial, hence it needs to be a mandatory requirement for port entry (Fig. 5).

BWRF needs to be submitted on time and properly filled-in. BWRF needs to be submitted as soon as possible; e.g., when the vessel knows what ballast water operation is expected in the next port of call. PSA needs to have a submission deadline, e.g., 48 h before a vessel enters the waters of its jurisdiction. Early submission may not always be possible because two ports may be too closely located. In such a case it is recommended that the vessel submits the BWRF upon leaving the last port of call. Early submission of BWRF is critical to give the PSA sufficient time to take a decision on appropriate BWM measures, as well as for the vessel to be in a position to conduct the required BWM practice.

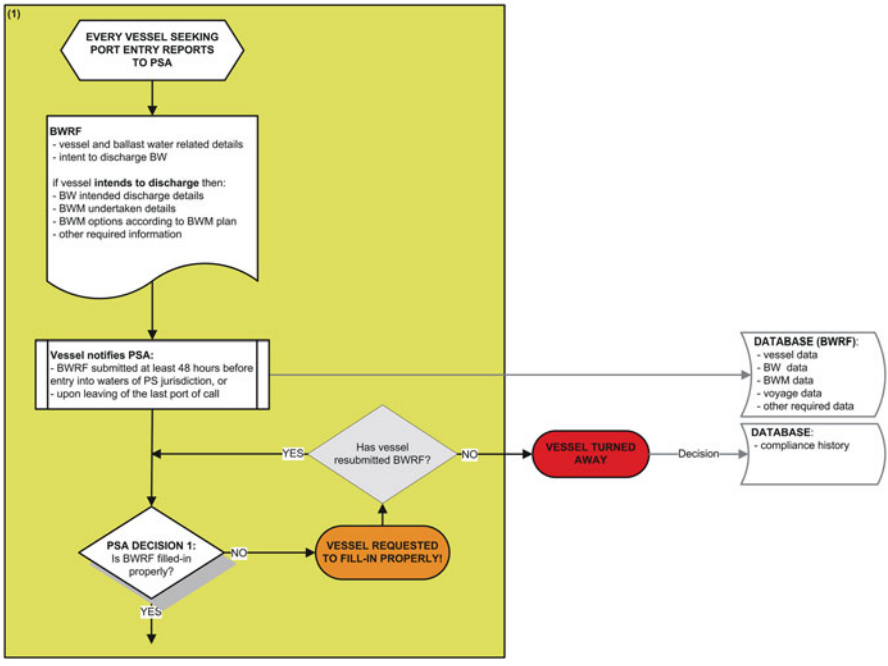

Fig. 5 BWRF submission process (*PS* Port State) (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

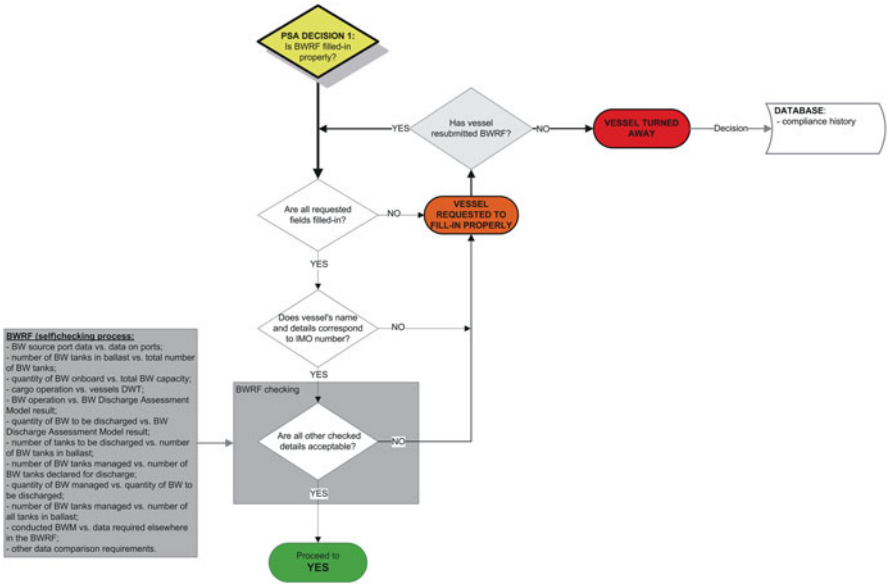

Fig. 6 Decision (1) on correct BWRF submission (*DWT* Dead Weight Tonnage) (This figure can be downloaded from http://extras.springer.com/)

Decision 1: Was BWRF Filled-In Properly?

BWRF has to be filled-in properly to start the DSS procedure. It is absolutely critical for the PSA, i.e., DSS, to have all requested data available to be able to take a proper BWM decision. Omissions, mistakes, as well as false-reporting can be anticipated. Therefore, the data provided need to be checked quantitatively as well as qualitatively. The vessel cannot obtain a port entry permit if it does not submit all required data (same practice as for other required reporting). Such cases are also registered in the "compliance history" database (see Fig. 6).

In the first two steps the BWRF is checked to ensure that all requested fields are filled-in and that the vessel's basic data correspond with the IMO number. If this is not satisfactory, the BWRF should not be accepted and the vessel becomes automatically turned away. In case an electronic submission system is used, this can be checked automatically and the BWRF does not need be submitted on paper.

In the third step, the submitted data is further checked qualitatively (see Fig. 6, grey box on the left).

The checking process includes:

The ballast water source port data (e.g., UN LOCODE port code, name, geographical position) needs to be confirmed to ensure true data for the source of ballast water intended to be discharged. This is important for the assessment of different vessel voyage related data, however this is absolutely critical for the RA data needs, and includes biological and environmental data. The UN LOCODE port code is the suggested triggering reference. An electronic system may be used to check this automatically which may also be done for elementary port data. In case there is no

UN LOCODE data provided for the relevant source port, the vessel needs to provide its name (in English) and geographical position.

The number of ballast tanks in ballast is to be compared with the vessel's total number of ballast tanks. The declared number of filled ballast tanks in no case can be larger than the vessels total number of ballast tanks. This can be compared automatically by the electronic system, which does not allow a higher tank number to be entered in the BWRF.

The quantity of ballast water on board is to be compared with the vessel's total ballast water capacity. The declared ballast water quantity on board in no case can be higher than the vessels total ballast capacity. The electronic system can compare these numbers automatically and does not allow a higher amount of ballast water to be entered in the BWRF.

The cargo operation (i.e., quantity in tons of cargo to be loaded or discharged) in no situation can be greater than the vessel's maximum dead weight tonnage (DWT) capacity.[5] The maximum cargo capacity is actually expected to be approximately 10 % lower than the vessels maximum DWT capacity. The electronic system can compare these numbers automatically and does not allow a greater number to be entered in the BWRF. This information is also critical for the assessment (verification) of expected (reported) ballast water operations in the related port, which is automatically done by the BWDA model.

A ballast water operation is to be expressed in terms of the expected ballast water quantity to be discharged or loaded in the related port. The declared operation, as well as the declared quantity of ballast water intended to be discharged, are to be compared with the BWDA model result. A mismatch in operation (i.e., no discharge declared but the model shows a discharge) as well in quantity (i.e., the model assessed discharge quantity of ballast water is substantially bigger than declared) triggers suspicion that there is a mistake in reporting, or even false reporting. However, it is not suggested that this would automatically prevent BWRF submission and the vessel to be turned away, but this information is to be used later as the trigger in the compliance monitoring process.

If the vessel has declared that it will discharge ballast water in the port, the number of ballast tanks to be discharged is to be compared with the number of tanks in ballast. The declared number of ballast tanks to be discharged in no case can be higher than the number of tanks in ballast. Again, the electronic system can compare these numbers automatically and does not allow a higher number to be entered in the BWRF.

If the vessel has declared to have already managed the ballast water intended for discharge, the number of ballast water tanks managed is to be compared with the number of ballast water tanks to be discharged. The declared number of ballast water tanks managed can be greater or lesser than the number of ballast water tanks declared for the discharge. In practice it is not expected that a vessel would conduct

[5] i.e., vessel's carrying capacity, which includes cargo and all weights (e.g., fuel, ballast water, stores), crew and passengers that may be loaded onboard a vessel up to her permissible limits, which is regulated by IMO international conventions, mainly the Load Lines Convention.

BWE for tanks if these are not intended to be discharged, hence a higher number of those BWE managed tanks would most likely be a mistake. However, as a consequence of using BWMS (i.e., treatment of ballast water to meet the D-2 standard) which treats ballast water on uptake, this would be a regular result. In case the declared number of ballast water tanks managed is lower than the number of ballast water tanks declared for the discharge, it is necessary to confirm whether this is a mistake or there are tanks with ballast water that need to be considered in the next steps by the RA process. The numbers need to be compared as follows:

- if the number of managed tanks is greater than the number of tanks declared for the discharge, allow submission of BWRF with no further questions;
- if the number of managed tanks is lower than the number of tanks declared for the discharge, the vessel needs to correct this to have the same numbers, or declare the tanks that have not been managed, but are to be discharged (i.e.; Number of tanks to be discharged = Number of managed tanks to be discharged + Number of unmanaged tanks to be discharged). Should these BWRF entries not match, then the BWRF should not be allowed to be sent or not be accepted by the PSA.

Whichever BWM method has been declared, it should be confirmed that tanks declared for the discharge are those which were managed. The electronic system can compare this automatically and act as appropriate.

The quantity of ballast water managed is to be compared with the quantity of ballast water to be discharged. This is an analogue process, a comparison of the number of ballast water tanks managed vs. the number of ballast water tanks declared for discharge as described above. Hence, the same procedure is to be applied using "quantity of ballast water" instead of "number of tanks".

The number of ballast water tanks managed is to be compared with the number of all tanks in ballast. The declared number of ballast water tanks managed in no case can be greater than the number of all tanks in ballast. The electronic system can compare these numbers automatically and does not allow a greater number of tanks with managed ballast water compared to all tanks in ballast be entered in the BWRF to be submitted.

The conducted BWM is to be compared with the data required elsewhere in the BWRF. If a vessel has declared that it has already conducted BWM also stating the BWM method used, there is a need also to report the number of managed tanks with the quantity of ballast water managed, and if BWE was used as BWM method, it needs to be reported where this was conducted. The BWM method declared and further information requirements need to be related quantitatively, i.e., all fields related need to be filled-in, and when possible also qualitatively.

Since this is a generic DSS model, it is expected that when it is applied, regional and national specific requirements may result in a need to add different 'other' data comparison requirements.

If a vessel reports satisfactory, then it enters the next phase of the DSS process, in which she is being selected to enter the RA process.

Selection of a Vessel for the RA Process

The selection of a vessel that will need to enter the RA process is done on the basis of data submitted via BWRF. Basically, all vessels which have declared an intention to discharge unmanaged ballast water in the port are selected for the RA process.

If a vessel has declared that it has ballast water on board which will not be discharged, such a vessel will not enter the RA process but will be notified that no BWM requirements apply to her and she is cleared to proceed. However, theoretically every vessel carrying ballast water and coming into a port has the potential to discharge ballast water, and in view of possible false reporting, such a vessel is checked with the BWDA model (see chapter "Vessels and Ballast Water"). The foreseen ballast water operation is assessed on the basis of expected cargo operations and vessel's particulars. If the BWDA model result disagrees with the declaration, the vessel will be targeted for the verification process.

If a vessel declared that she has already managed the ballast water intended for discharge, then she will be, in the next two steps, checked for her trustworthiness and the acceptability of the BWM method used. If she is found not trustworthy or the BWM used was not acceptable, than she will enter the RA process. If a vessel was not selected for RA process she is clear to proceed (see Fig. 7).

Decision 2: Is Vessel Trustworthy?

The main reason for introducing trustworthiness is the human factor. It is known that false reporting occurs and that it is very difficult to survey it. There are also many other reasons, some of the outstanding are low quality of vessel systems maintenance, low crew skill level, sometimes also ignorance. These, however, are also critical for proper and safe functioning of vessel systems.

Trustworthiness is focussed on the history of the false reporting of responsible crew members, as well as on the vessel compliance history. False BWM reporting related to a person may be kept in the records lifelong or time dependent, i.e., valid for a certain period of time, e.g., 10 years. The vessel BWM compliance history and general compliance is time dependent (see Fig. 8).

Decision 3: Is Ballast Water Management Acceptable?

If a vessel declares that it has already conducted BWM, this needs to be compared with the port State BWM requirements. The decision relies on the information provided in the BWRF.

All ballast water tanks that are intended for discharge need to be managed and the BWM method used is generally accepted if it fulfils the requirements of the BWM Convention and/or those of the port State. It is also important that the vessel follows procedures and requirements of the BWMS manufacturer and classification society (see Fig. 9).

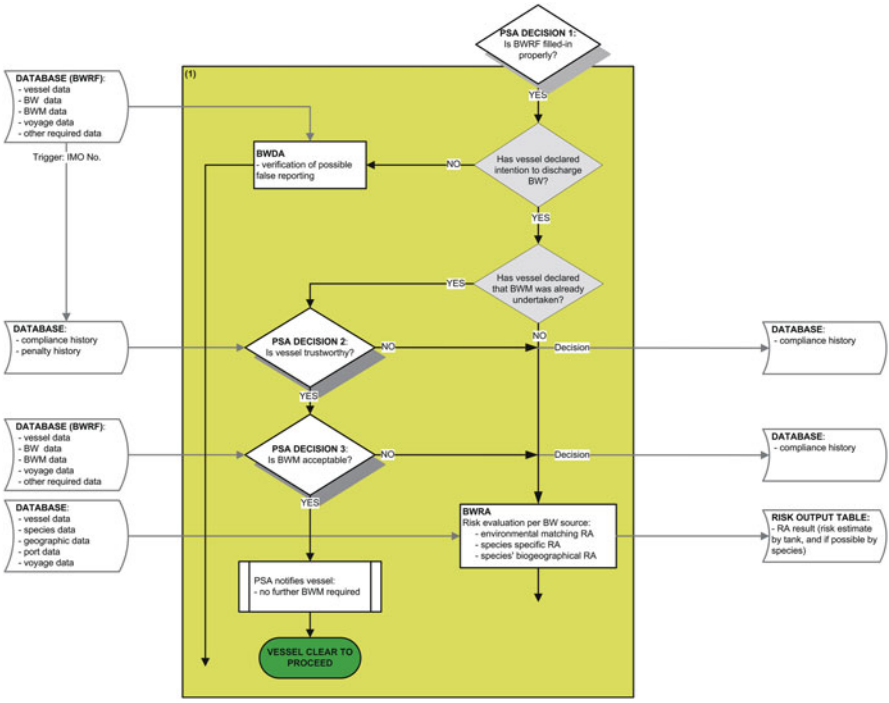

Fig. 7 Selection of a vessel for the RA process (Enhanced after David 2007). The *open arrow* going down from the BWDA box is directed to connect to the *Decision 6*: *Is vessel selected for CME process*? (see section "Decision 6: Vessel Selected for Compliance Monitoring and Enforcement Process?"). The *open arrow* going down from the BWRA box is directed down to connect to the *Decision 4*: *Is risk acceptable*? (see section Decision 4: Is Risk Acceptable?) (This figure can be downloaded from http://extras.springer.com/)

Ballast Water Risk Assessment Process

In this phase of the DSS process RA is undertaken to provide for adequate BWM based on the acceptability of the risk level assessed.[6] If the level of risk is acceptable, then the vessel will be cleared to proceed without conducting BWM. However she may still be selected for the verification process. If the level of risk is not acceptable, the vessel will need to undergo a BWM procedure (see Fig. 10).

Decision 4: Is Risk Acceptable?

The risk assessment process is in detail described in chapter "Risk Assessment in Ballast Water Management" and covers RA background, principles, RA end points, RA methods, RA errors and the application of RA under the BWM Convention.

[6] this is dependent on the port State environmental legislation, and the perception, values and ethics of the assessors.

Fig. 8 Decision (2) on vessel trustworthiness (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

For the purpose of this BWM DSS, the BWRA model presented in chapter "Risk Assessment in Ballast Water Management" is to be applied to assess the level of risk for selective BWM measures. When the level of risk assessed is extreme, high or intermediate, it is deemed not to be acceptable (see Fig. 11).

Ballast Water Management Process

BWM requirements apply to a vessel when the risk posed by the ballast water intended for discharge is deemed unacceptable. This includes the selection of a feasible (for the vessel) and acceptable (for PSA) BWM method according to the level of risk posed, which is followed by consequences if the required BWM measure is not applied.

There may be different instances when a vessel may not be able to conduct BWM (e.g., route too close to the shore, bad weather and sea conditions, some issue with the BWMS). In those instances, the PSA needs to take a decision whether to allow the vessel to discharge unmanaged ballast water, or use (if available) some alternative

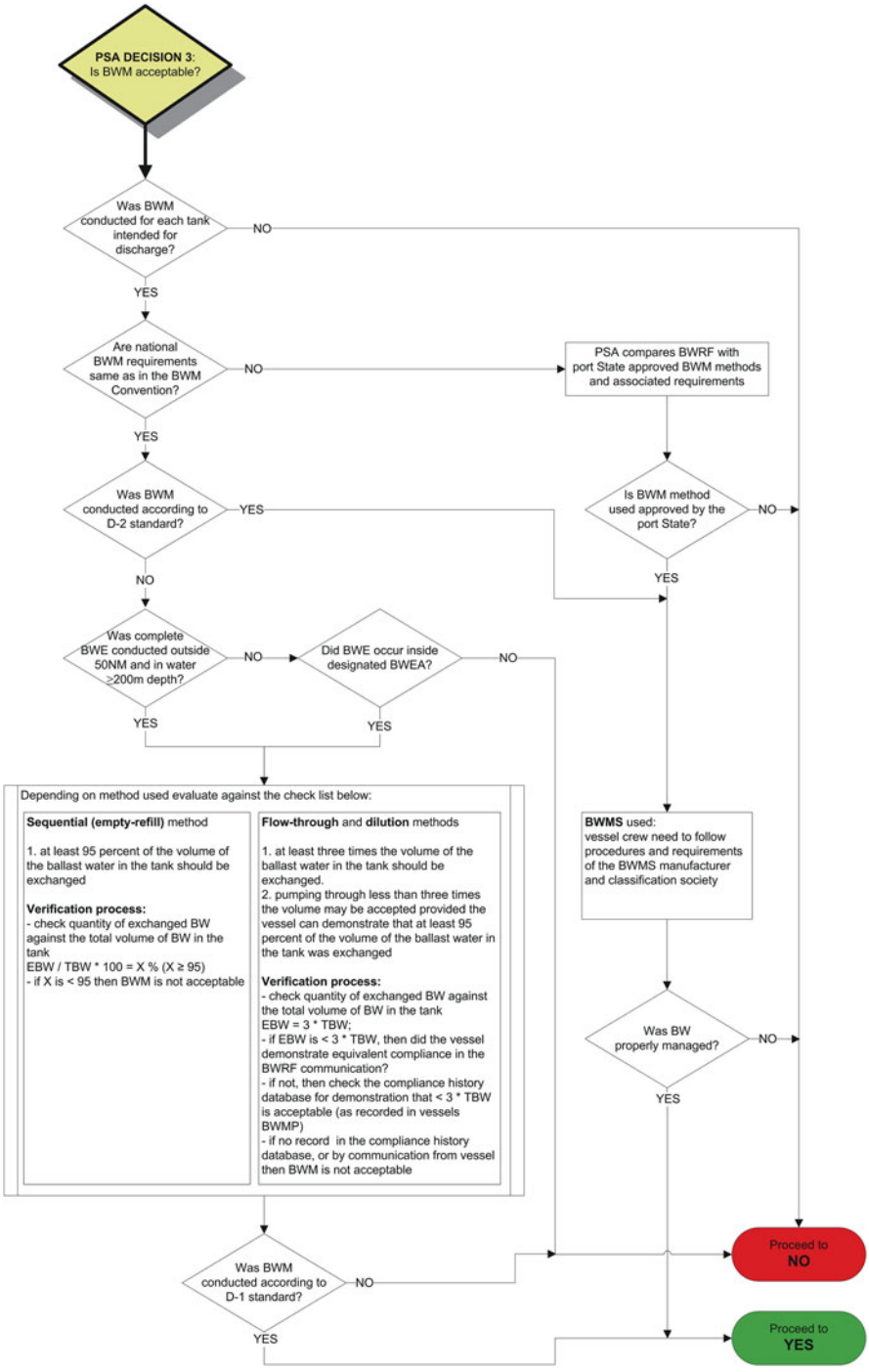

Fig. 9 Decision (3) on acceptability of BWM conducted (Enhanced after David 2007). *BWE* Ballast Water Exchange, *BWEA* Ballast Water Exchange Area, *BWMP* Ballast Water Management Plan, *BWMS* Ballast Water Management System, *D-2 standard* D-2 standard of the BWM Convention, *Reg. B4 and D-1 standard* Regulation B4 and D-1 standard of the BWM Convention, *EBW* Exchanged Ballast Water, *TBW* Total Ballast Water (This figure can be downloaded from http://extras.springer.com/)

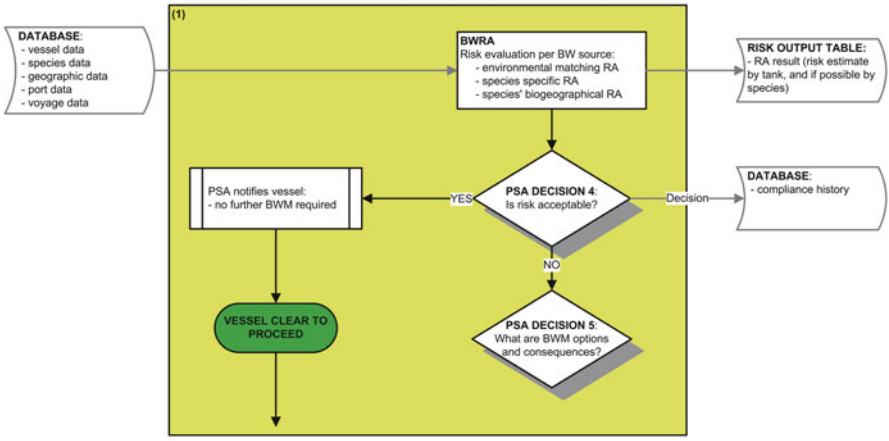

Fig. 10 The BWRA process (Enhanced after David 2007). The *open arrow* going down from the *green box* is directed to connect to the *Decision 6*: *Is vessel selected for CME process*? (see section "Decision 6: Vessel Selected for Compliance Monitoring and Enforcement Process?") (This figure can be downloaded from http://extras.springer.com/)

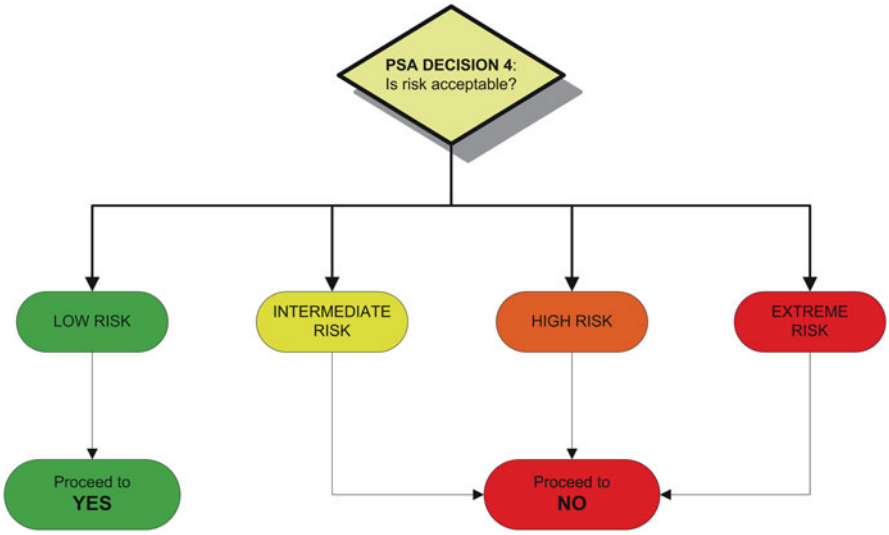

Fig. 11 Decision (4) on whether or not the risk posed by the ballast water intended for discharge is acceptable (This figure can be downloaded from http://extras.springer.com/)

option, retain the ballast water onboard, or in most critical situations to turn the vessel away. All these decisions are dependent on the risk level posed by the ballast water intended for discharge, by the vessel BWM options and the availability of alternative BWM options (see Fig. 12).

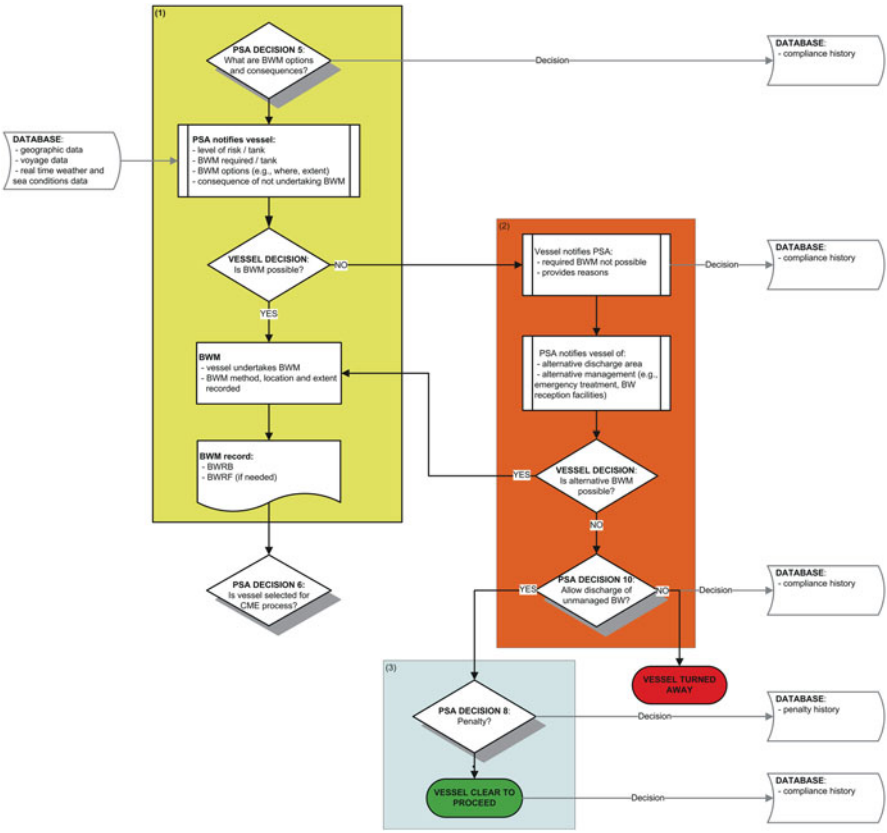

Fig. 12 BWM process (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

Decision 5: What Are Ballast Water Management Options and Consequences?

Retaining ballast water on board the vessel is considered as the first BWM option. This is only a feasible option for some vessel types with smaller ballast water capacity and especially in cases when vessels are only partially loading. If necessary the vessel might manage it by pumping ballast water from one tank to another without any discharge to the port. If this cannot be done, that ballast water would need to be managed.

If a vessel is capable of managing ballast water according to the BWM Convention D-2 standard, then it does so and is clear to proceed. If a vessel does not have BWMS installed, then BWE would need to be conducted as minimum BWM measure.

If the vessel is capable of properly conducting BWE on the intended route[7] for all the ballast water intended for discharge, and the port State accepts the BWE method, then the vessel does so and is clear to proceed. If not, then the use of BWEA or alternative options are to be considered according to the level of risk posed. Certainly, BWEA needs first to be designated, and/or the alternative options need to be studied, be available, and be feasible for vessels. Alternative options include ballast water reception facilities which may be made available in the port or an alternative discharge area may be found more appropriate for discharge of unmanaged ballast water. If a ballast water reception facility would be made available, the vessel would need to have additional piping installed to enable ballast water discharge in such a facility. If possible, partial BWM is to be conducted still on the intended route, and may be then continued and finalised in the BWEA or as alternative method. Partial BWM means that on the intended route proper BWM is conducted on a limited number of tanks, e.g., BWE according to the D-1 standard is conducted for as many tanks as possible, e.g., four out of eight tanks intended for discharge, and the remaining four are then left for BWE in the BWEA area, for alternative management options, and some ballast if necessary may also be retained on board.

If a BWEA is designated according to the BWM Convention provisions, vessels may use it if they sail through it on their intended route or if they choose to deviate, though this is a decision of the ship's Master. Hence, it can be anticipated that vessels will unlikely use BWEA by default; and even less so can it be expected that vessels deviate or slow down to complete the BWE within a BWEA. Therefore, a port State needs to have provisions in place to advise the vessel what to do. The requirements to regulate the BWE in the relation to the BWEA are not deemed as additional measures by the BWM Convention. However, most alternative options will be deemed as such and need to be addressed according to the provisions of the BWM Convention for additional measures (see chapter "Policy and Legal Framework and the Current Status of Ballast Water Management Requirements").

One of the very important aspects for appropriate BWM is that a vessel does not exchange the ballast water on board with water that is of a greater risk, e.g., areas with toxic algae blooms, which may occur in the BWEA. Even if the water in the BWEA is of the same risk level, BWE should not be conducted since the "older water" in the tanks is expected to be of lesser risk than the "new" exchanged water and can therefore lead to increased risk by adding, e.g., new nutrients or new organisms to the ballast tank. In consequence, as by the IMO *Guidelines on designation of areas for ballast water exchange* (G14) a BWEA should be monitored for HAOP. In case of HAOP presence in the BWEA, the vessels need to be instructed as appropriate to avoid BWE in this area (IMO 2006).

The following BWM options and consequences have been included if BWEA and/or alternative BWM options are available:

[7] The vessel may also consider a slight deviation and change "the shortest" route to be able to conduct BWE according to the BWM Convention limits, i.e., >50 NM distance of shore and >200 m of depth.

If the ballast water to be discharged was assessed as posing an intermediate risk, then:

- if a vessel crosses BWEA on its intended route, then she is requested to conduct BWE, but only if the water in the BWEA poses a low risk; however
- if a vessel is not able to fully complete BWE in a BWEA, here a deviation or slowing down is not meant to be requested.

If it was not appropriate or the vessel was not able to conduct or fully complete BWE in the BWEA, she will be:

- allowed to discharge unmanaged ballast water in the port; and
- targeted for a verification process.

If the ballast water to be discharged was assessed as posing a high risk, then:

- if a vessel crosses BWEA on its intended route, then she is requested to conduct BWE, but only if the water in the BWEA poses low or intermediate risk;
- if a vessel does not cross BWEA on its intended route, then she is requested to deviate a reasonable distance[8] to use the BWEA;
- if a vessel is not able to complete full BWE while crossing the BWEA, then she is requested to slow down or take other measures to fully complete BWE; and
- if a vessel was not able to conduct BWE or fully complete BWE in the BWEA, then she is requested to conduct alternative BWM.

If it was not appropriate or the vessel was not able to conduct or fully complete BWE in the BWEA, and the vessel has no further option to conduct alternative BWM, she will be:

- allowed to discharge unmanaged ballast water in the port; and
- targeted for a verification process.

If the ballast water to be discharged was assessed as posing an extreme risk, then:

- if a vessel crosses BWEA on its intended route, then she is requested to conduct BWE, if the water in the BWEA poses low, intermediate or high risk;
- if a vessel does not cross BWEA on its intended route, then she is requested to deviate in a reasonable distance to meet the BWEA;
- if a vessel is not able to complete full BWE while crossing BWEA, then she is requested to slow down or take other measures to fully complete BWE; and
- if a vessel was not able to conduct BWE or fully complete BWE in the BWEA, then she is requested to conduct alternative BWM.

If it was not appropriate or the vessel was not able to conduct or fully complete BWE in the BWEA, and has no further option to conduct alternative BWM, she will be turned away, as at this stage it is assumed that operations in ports cannot be completed without discharging unmanaged ballast water.

The BWM options and consequences are shown in Fig. 13.

[8] Reasonable distance is to be decided based upon regional specifics and deviation related costs.

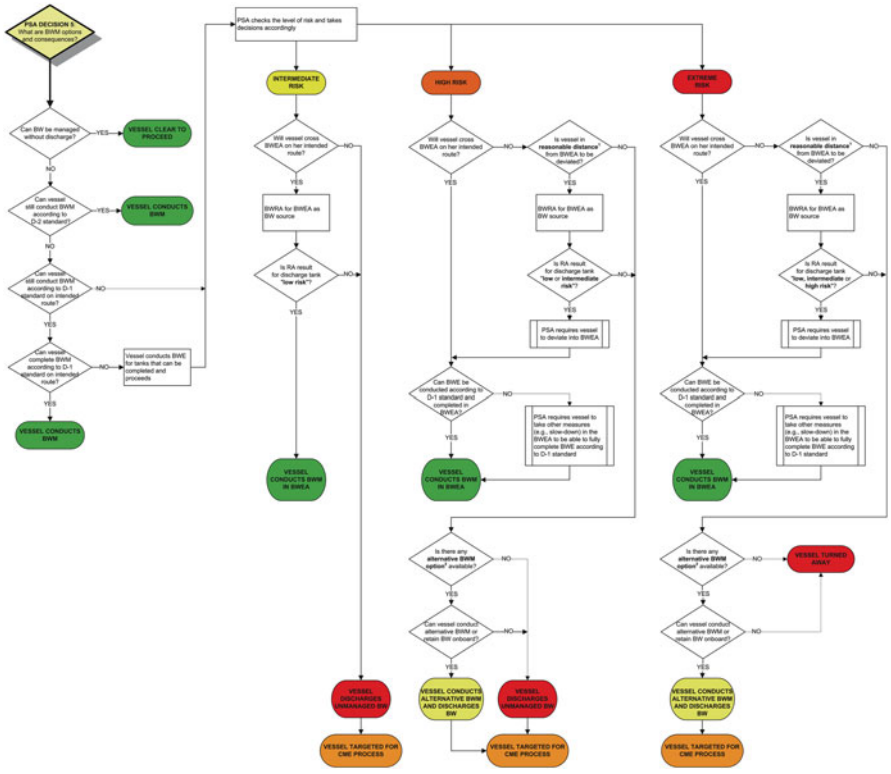

Fig. 13 Decision (5) on BWM options and consequences (Enhanced after David 2007). (*1*) reasonable distance – to be decided based upon regional specifics and deviation related costs; (*2*) alternative BWM option – alternative ballast water discharge area or alternative management, e.g., emergency treatment, BW reception facilities (This figure can be downloaded from http://extras.springer.com/)

After the BWM action has ended and the vessel has undertaken (or not) the required BWM practice, she may be selected for the verification process to verify compliance with the requirements, i.e., compliance monitoring and enforcement (CME) process.

Compliance Monitoring and Enforcement

The CME process is in the first place intended to back-up the management process, and to support the full implementation of the BWM Convention and any further port State BWM requirements. Every vessel allowed to enter the port may be selected for compliance monitoring. If a vessel is found not compliant, but has already entered the port and started deballasting, it may be stopped from deballasting and may be requested to take alternative BWM measures. The compliance monitoring process is followed by the penalty process for non-compliant vessels. A penalty

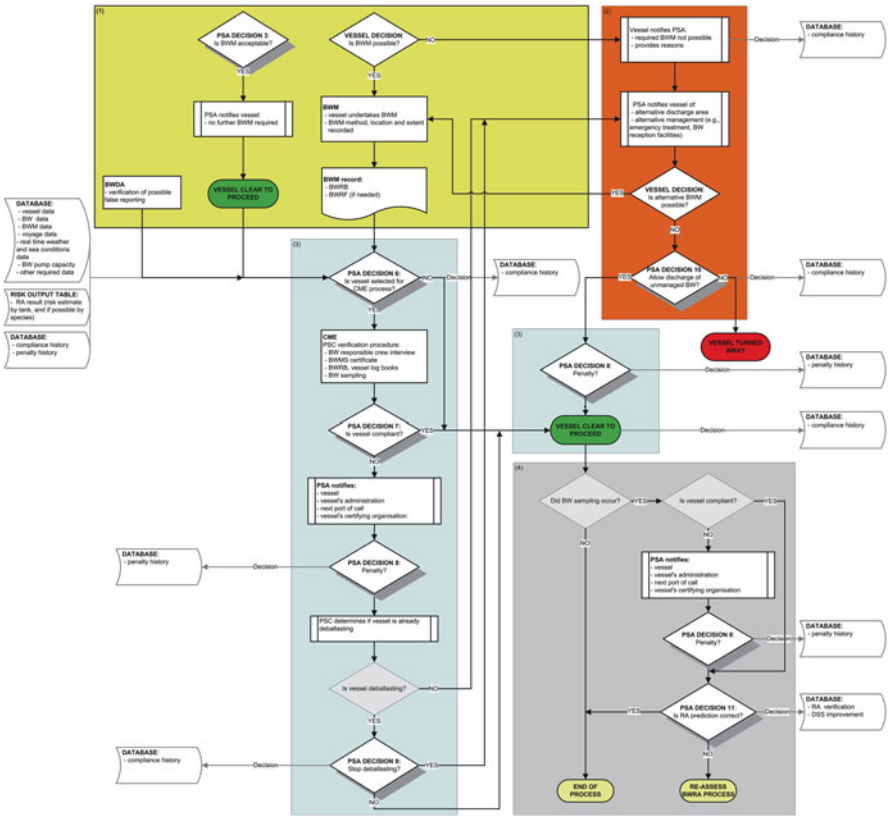

Fig. 14 Compliance monitoring and enforcement process (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

may be applied to a non-compliant vessel when she is still in the port or even when she has already left the port, depending on when the non-compliance is identified/confirmed. A vessel may be found non-compliant when in the port, e.g., when not carrying a valid BWMS certificate, or the non-compliance may be confirmed when the vessel has already left the port, e.g., when BWS for compliance monitoring was undertaken however analyses took longer then her stay in the port (see Fig. 14).

Decision 6: Vessel Selected for Compliance Monitoring and Enforcement Process?

The CME process is conducted by PSC and starts with the vessel selection. If PSC has a separate BWM CME programme, a random selection with a minimum number of vessels targeted, may be conducted. However, if there is no BWM specific programme adopted, then PSC may select a vessel for the BWM CME process

while undertaking an inspection under the already implemented regular inspection programme. Further to such programme, BWM specific elements to trigger the CME process have been identified. According to the BWM Convention, the verification process has two levels. Triggering elements have been grouped accordingly. Each of these can trigger the compliance monitoring process directly or randomly. A vessel targeted by the selection process enters the CME process. According to the BWM Convention Article 9, a vessel to which the BWM Convention applies may be subject to inspection in any port or offshore terminal of the port State that is party to the BWM Convention. The purpose of such inspection is determining whether the vessel is in compliance with the BWM Convention. Even if the BWM Convention has not yet entered into force, every state has to provide for an effective verification process to support effective implementation of the BWM measures.

The verification process has two levels, the "regular inspection" and the "detailed inspection". The main differences of the two levels are the triggering elements, as well as the consequences for the vessel during the inspection process.

The so called regular inspection does not need special justification for the triggering elements, and as such can be understood as part of the basic and regular PSC inspection process. It can be further divided into simple paper inspection and BWS for compliance. The simple paper inspection includes:

- verification that there is a valid BWMS certificate on board the vessel;[9] and
- inspection of the BWRB.

BWS for compliance has basically two different approaches:

- BWS for salinity (D-1 standard compliance); and
- BWS for D-2 standard compliance.

The BWS for salinity is generally intended to be used for a verification of the BWE process, and specifically for the verification of the RA process when a decision was taken based on environmental matching salinity. The BWS for compliance with the D-2 standard requires analyses of viable aquatic organisms present in the ballast water.

The BWS for compliance should be conducted according to the Guidelines for ballast water sampling (G2) (IMO 2008) and its related guidance documents. If BWS is conducted as a part of the regular inspection, the vessel shall not be unduly delayed for the time required to analyse the ballast water samples. For more details about BWS see chapter "Ballast Water Sampling and Sample Analysis for Compliance Control".

A PSC may also decide to carry out a detailed inspection when a ship does:

- not carry a valid BWMS certificate; or there are
- clear grounds for believing that:

[9] If valid, it shall be accepted.

- the vessel or its equipment does not correspond substantially with the particulars of the certificate; or
- the master or the crew are not familiar with essential shipboard procedures relating to BWM, or these have not been implemented.

The detailed inspection includes, as appropriate:

– the inspection of all needed documents and log books;
– the inspection of the vessel (e.g., BWMS);
– indicative BWS.

When a PSC decides to carry out the detailed inspection, the vessel shall not discharge ballast water until it is confirmed that it can do so without risk of harm to the environment, human health, property or resources (see Fig. 15).

Decision 7: Is Vessel Compliant?

PSC has conducted an inspection to check if the vessel has complied with the BWM requirements. PSC checks if the vessel is carrying a valid BWMS certificate, if the conditions of the vessel and the BWMS correspond with the BWMS certificate, interview the BWM responsible crew members if they are familiar with the BWM procedures and if these were implemented. Even if all these checks were satisfactory for PSC, they may decide to proceed with conducting BWS to ascertain that BWM measures implemented are acceptable and efficient (Fig. 16).

Decision 8: Penalty?

National legislation would need to provide for the prevention of unwanted impacts caused by discharges of HAOP via ballast water. Legislation would also need to cover unlawful acts of vessels flying their flag (i.e., Flag state), as well as those occurring in their jurisdictional waters (i.e., Port State). The penalty process in this DSS is focussed only on port State requirements.

If a violation has been detected, the PSC should see whether national legislation has provided for such an act and proceed accordingly. If a vessel is penalised, this needs to be recorded in the penalty history database. The sanctions provided should be of adequate severity to discourage further violations (see Fig. 17).

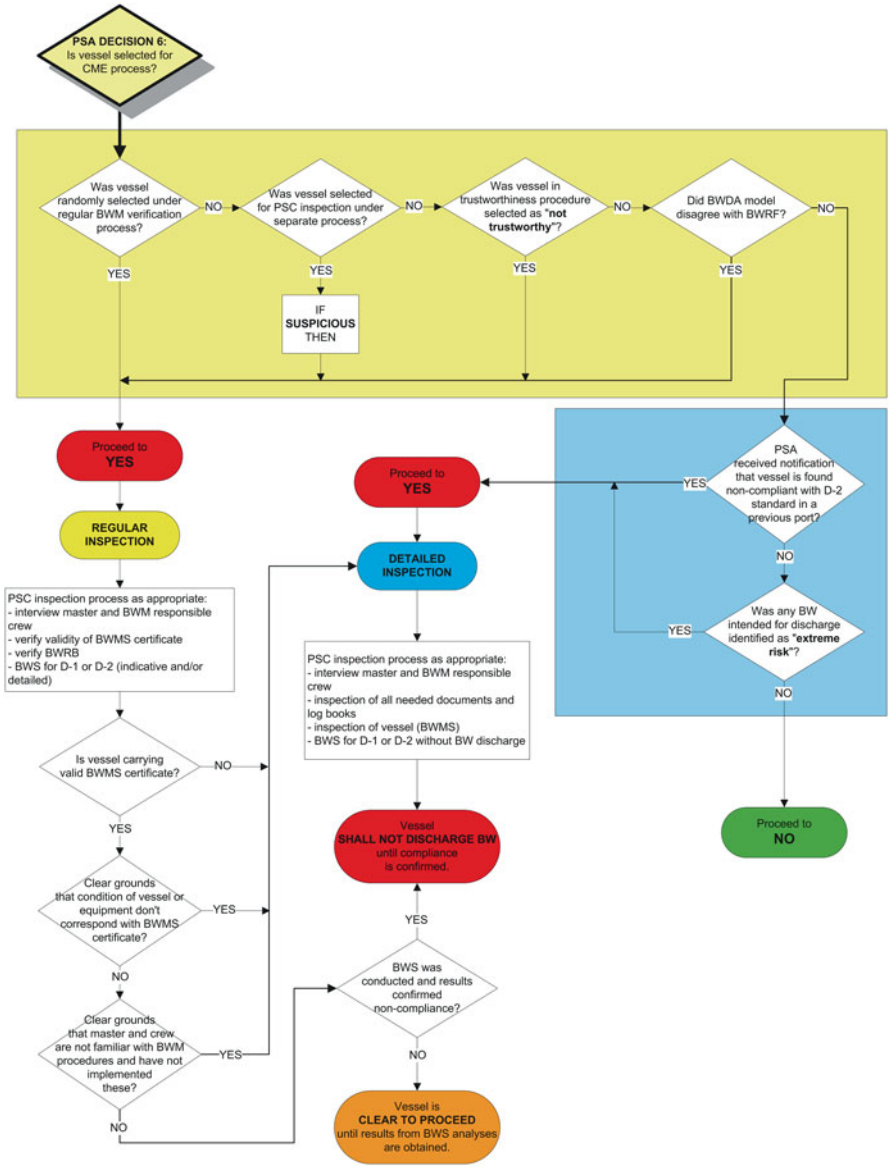

Fig. 15 PSA decision (6) on vessel selection for CME process, including the two different levels of inspection according to the BWM Convention, i.e., so called regular and detailed inspection (Enhanced after David 2007). The *light yellow box* includes elements that trigger the simple inspection; the *light blue box* includes elements that directly trigger the detailed inspection (This figure can be downloaded from http://extras.springer.com/)

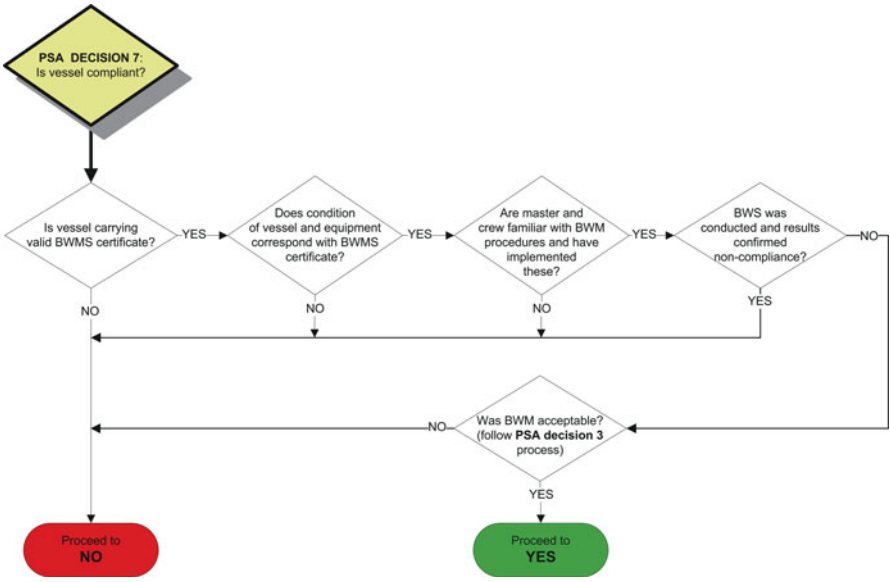

Fig. 16 PSA decision (7) on vessels compliance with the BWM requirements (This figure can be downloaded from http://extras.springer.com/)

Decision 9: Stop Deballasting?

If a vessel is found non-compliant with BWM requirements, PSC may decide to prevent deballasting. The decision regarding the prevention of a vessel from deballasting is basically related to the risk posed by the ballast water intended for discharge.

In case a non-compliant vessel has already started deballasting and the risk posed is unacceptable, such a vessel will be stopped from deballasting (see Fig. 18).

When a vessel was required to stop deballasting, the PSA authority notifies that vessel regarding possible alternative BWM options available. If feasible, the vessel conducts alternative BWM.

Decision 10: Allow Discharge of Unmanaged Ballast Water?

This is a position where none of the "regular" or alternative BWM options was implemented. A vessel in this situation would be one that:

- has declared to have on board unmanaged ballast water intended for discharge;
- did everything in her capability to comply with the requirements;
- was not able to conduct requested regular BWM practice; as well as
- was not able to conduct alternative BWM practices.

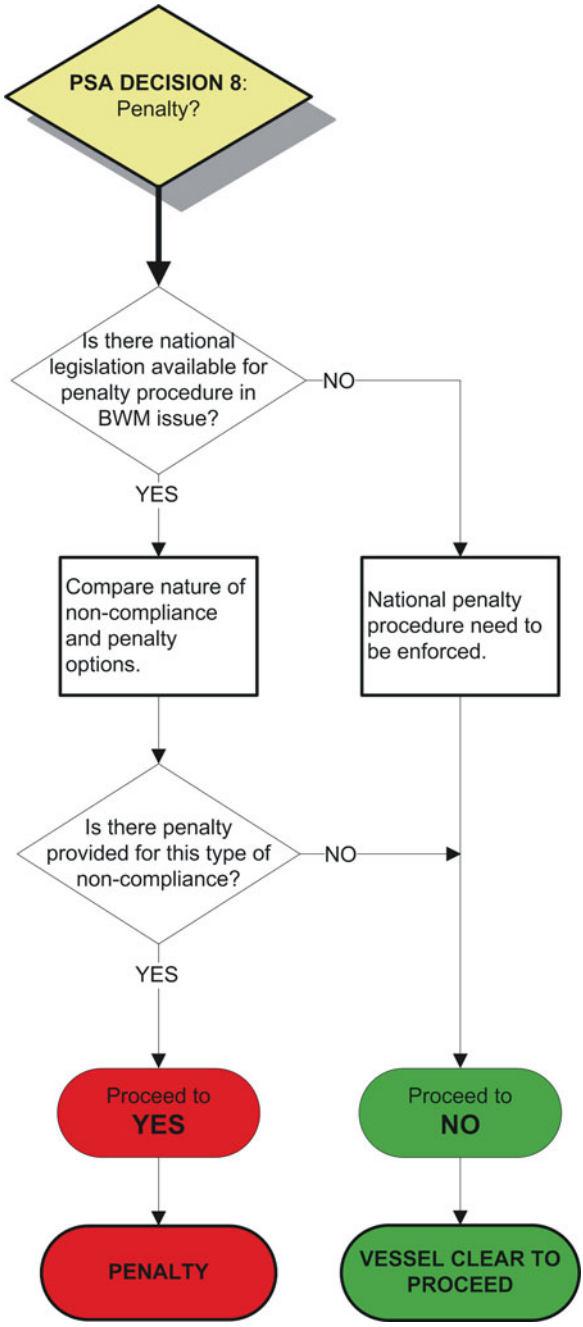

Fig. 17 Decision (8) on issuing a penalty to the non-compliant vessel (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

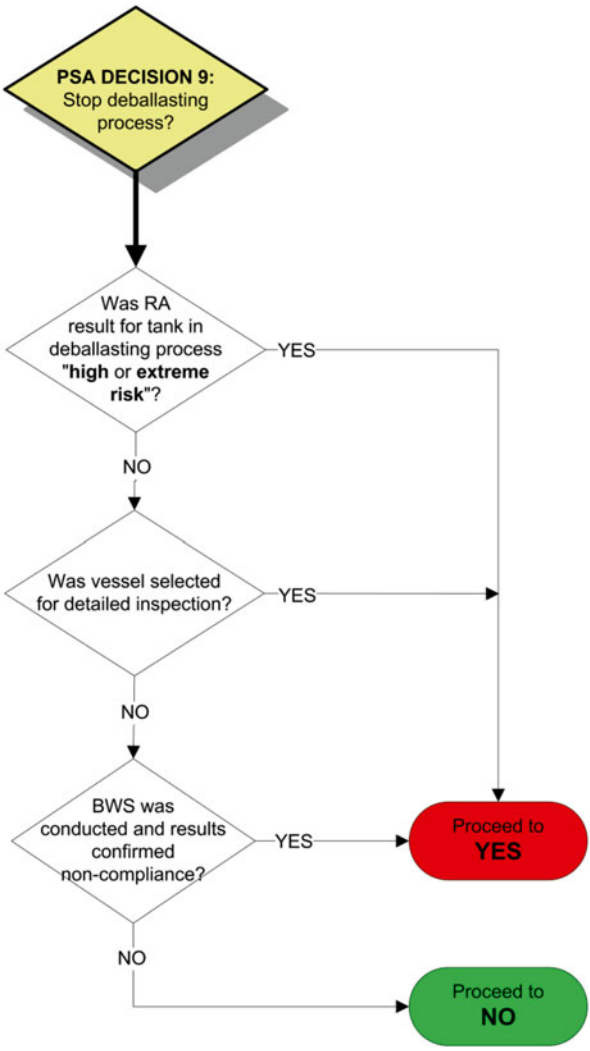

Fig. 18 Decision (9) on stopping a vessel to deballast (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

The PSA needs to take a decision whether or not to allow such a vessel to discharge unmanaged ballast water in the port or to turn it away. Such a decision should certainly be taken considering the risk posed by the ballast water intended for discharge. However, for the general practice and effectiveness of BWM measures it is also important that the vessel did everything in her capability to comply with the requirements. In this situation the PSA should check:

– BWM requirements according to the legislation;
– vessels' BWM options according to the BWM plan;
– intended route;

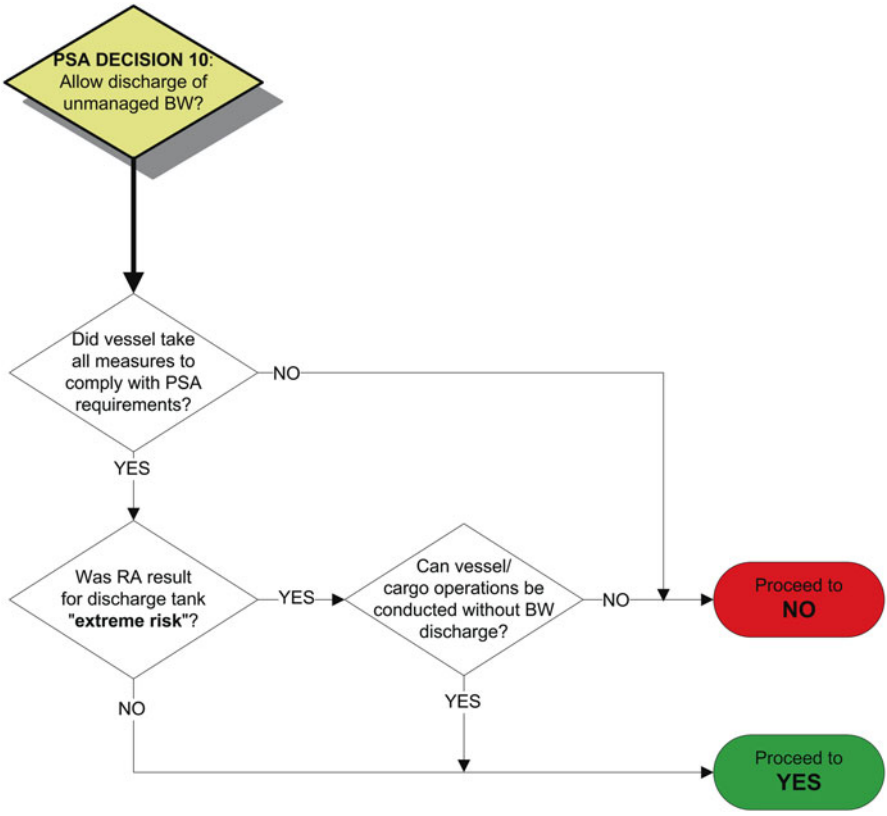

Fig. 19 Decision (10) on allowing or not a vessel to discharge unmanaged ballast water (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

– voyage duration and other conditions;
– vessels capability to conduct alternative BWM options; and
– the result of RA.

In case a vessel took all measures to comply with the requirements, including alternative BWM options, then the level of risk posed by the ballast water intended for discharge needs to be verified. If the ballast water was assessed as of extreme risk, than the vessel should not be allowed to discharge ballast water, however in cases when the risk level assessed was intermediate or high, the vessel may still be allowed to discharge ballast (see Fig. 19).

Certainly, this should be understood only as minimum criteria. It is up to each PSA to decide whether or not to apply a more stringent approach and possibly not allow discharge of unmanaged ballast water that was assessed as high or even intermediate risk which would be desirable especially from an environmental perspective.

BWRA Review Process

BWRA is a relatively new field of work and will certainly need to be improved over time. The basis for improvement should be found when more knowledge and information becomes available by experience. Especially the results of BWS for compliance may be a very valuable source to be used for the review process of BWRA, and findings may support BWRA improvements (see Fig. 20).

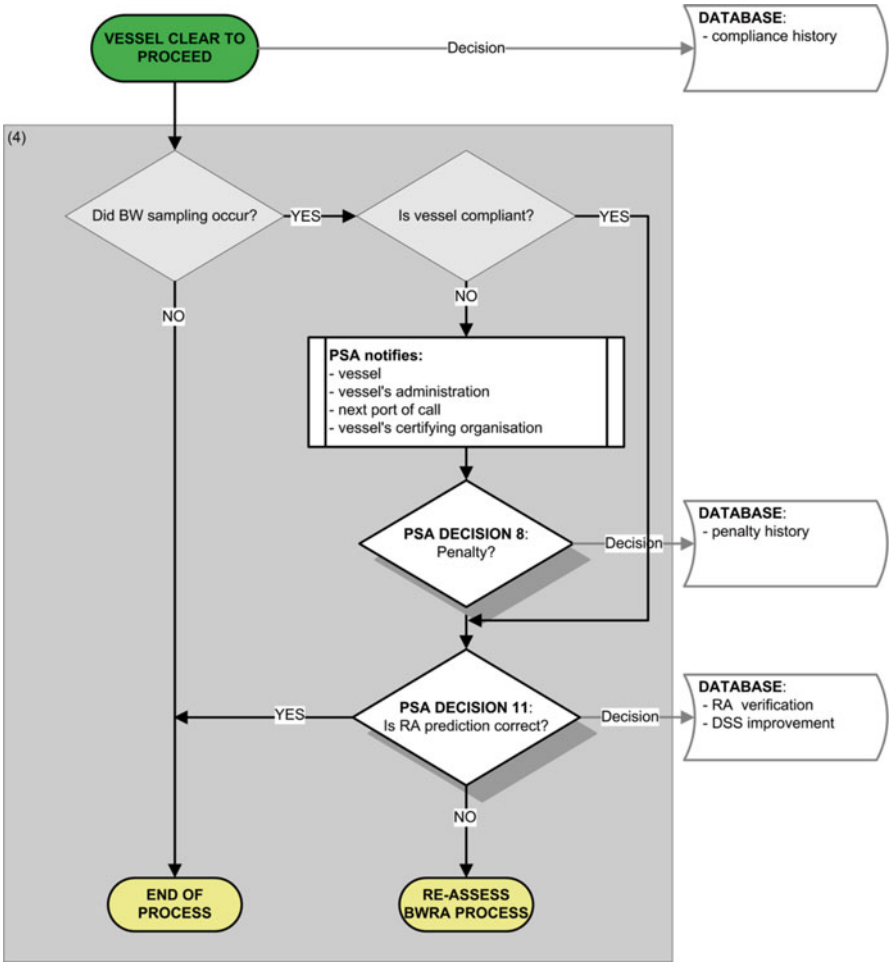

Fig. 20 The BWRA review process (Enhanced after David 2007) (This figure can be downloaded from http://extras.springer.com/)

Decision 11: Risk Assessment Prediction Correct?

The process is based on the comparison of the BWRA result with the BWS result. BWS may be conducted just for salinity, may encompass biological analysis focussed on the presence of viable organisms as per the D-2 standard, or may also include identification of HAOP. If only a salinity test was undertaken, then the results may be used only for the review of the BWRA that was based on environmental matching, while also an identification of HAOP is needed for a complete review of BWRA (see Fig. 21).

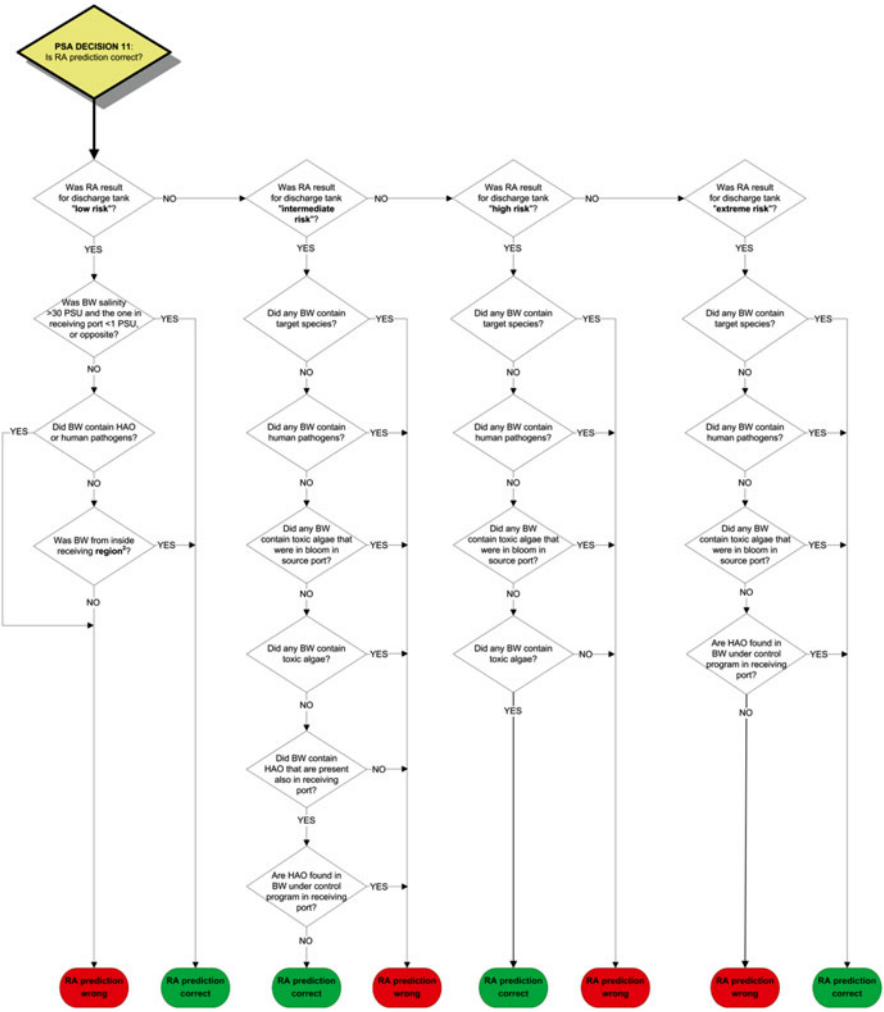

Fig. 21 Management decision (11) on correctness of the RA result (Enhanced after David 2007). *PSU* Practical Salinity Unit, *HAO* Harmful Aquatic Organisms (This figure can be downloaded from http://extras.springer.com/)

End-Points of the DSS

The selective approach in the process of BWM based on this DSS may result in one of the following situations:

- vessel is turned away because she has not submitted required data;
- vessel does not need to discharge ballast water;
- vessel may conduct BWM in advance;
- vessel is exempted from BWM requirements based on BWRA;
- vessel requested to conduct BWM may be able to comply or not;
- vessel requested to conduct BWM may do it properly or not;
- vessel may be selected for CME;
- vessel may be allowed to discharge unmanaged ballast water;
- vessel was able to comply with BWM requirements, but did not conduct BWM at all so she is turned away;
- vessel was able to comply with BWM requirements, but did not conduct BWM properly so she is turned away;
- sampling from CME reveals that BWM standards are not met so that the deballasting has to be stopped; or
- vessel found not in compliance may be penalized.

In addition to the decisions relating to BWM, a reassessment of the RA procedure is provided in the DSS process, which is important for further improvement of RA results.

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