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REVIEW OF STUDIES ESTIMATING IUU FISHING AND THE METHODOLOGIES UTILIZED

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A French and Spanish translations of the Abstract and Executive Summary will be available soon.

REVIEW OF STUDIES ESTIMATING IUU FISHING AND THE METHODOLOGIES UTILIZED

SUBMITTED TO

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BY

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Abstract

In February 2015 FAO convened a workshop in Rome, Italy, to consider methodologies for estimating IUU fishing at the global level. The workshop suggested that FAO could: (i) coordinate a 'Study of IUU fishing studies' to review the different methodologies being used to estimate IUU fishing; (ii) lead a process to develop technical guidelines for future studies so they could be conducted in a way that would allow for estimates to be combined to contribute to a global estimate; and (iii) consider indicators of IUU fishing for inclusion in FAO's bi-annual SOFIA publication.

The study of IUU fishing studies presented in this report has been completed by Poseidon (UK-based fisheries and aquaculture consultants working globally) and found that: (i) there are many different methodologies being used to estimate IUU catch but many estimates are not robust and methodologies not consistent; (ii) estimates of global "missing catch" made in some studies include catch that is not necessarily IUU in terms of the definitions in the IPOA-IUU; (iii) developing an updated global estimate of IUU catch may have limited benefit due to wide confidence intervals and a lack of clarity over IUU behaviors included; (iv) indicators of IUU fishing to monitor progress in combatting IUU fishing need not necessarily include global estimates of volumes of IUU fish, and could focus on other aspects such as numbers of vessels on IUU fishing vessel lists, the number of countries on the EU IUU 'yellow' and 'red card' lists, and selected regional or local estimates of IUU fish catch based on repeatable and robust methodologies; and (v) FAO might play a role in supporting the development of technical guidelines, both on methodologies for estimating IUU catch, and on how to conduct risk-based assessments of IUU fishing.

EXECUTIVE SUMMARY

Background

In 2009 a paper by Agnew *et al*[1] estimated that IUU-caught fish in 2003 was 11-19% of reported catches, representing 10-26 million tonnes of fish valued at US$10-23 billion. These eye-catching figures helped to further mobilize international, regional and national efforts to combat IUU fishing which had been gaining pace mainly since the mid 1990s and early 2000s. Many other studies have also been completed in recent years to estimate levels of IUU catches, and these studies have used a range of different methodologies to estimate levels of IUU fishing.

In February 2015, FAO it convened a workshop in Rome to consider methodologies for estimating IUU fishing at the global level. The premise underlying this workshop was that a new global estimate of IUU catch would be useful, as the 2009 paper estimating IUU-caught fish is now outdated both in terms of the 2003 estimate it provided and in terms of the changed international, regional and national context now influencing levels of IUU fishing. Concern has also been expressed over the wide range between the upper and lower estimates in the study, and over some of the methodological aspects and particularly the raising factors used to generate the global estimate.

In considering how methodologies for estimating IUU fishing could be improved and standardized to facilitate a global estimate of IUU catch, the February 2015 workshop suggested that FAO should: (i) coordinate a Study of IUU fishing studies (hereafter referred to as the 'study of studies') to categorize and review the strengths and weaknesses of the different methodologies being used to estimate IUU catches; and (ii) lead a process to develop technical guidelines for future studies so they could be conducted in a way that would allow for estimates to be combined to contribute to a global estimate. The workshop also suggested that FAO should consider indicators of IUU fishing for inclusion in FAO's bi-annual SOFIA publication, suggesting that a global estimate of IUU catches could be one such indicator to be included.

Methodology

In completing the study of studies, relevant studies were collected through: (i) literature searches for relevant peer-reviewed articles published in scientific journals; (ii) web-based searches to collect project reports and other relevant studies; (iii) requests through FAO to RFMOs for relevant studies; and (iv) participation by the consultants in the 5th Global Fisheries Enforcement Training Workshop (GFETW) held by the International MCS network in Auckland, New Zealand in March 2016, which afforded the opportunity to engage with more than 150 MCS practitioners from around the world to request copies of relevant studies. A total of 89 studies, journal articles and research reports were collected and reviewed. Forty-four of these were studies actually estimating levels of IUU fish catch, and for each one a summary fiche of half, to one page, was prepared to capture key information about the study which had been reviewed. A further 35 were studies which did not estimate IUU catch and which often instead just reported on compliance levels or individual IUU fishing events. The summary fiches for the 44 relevant studies were then analysed to draw out the key findings, conclusions and recommendations for FAO and COFI.

[1] Agnew, D.J., Pearce, J., Pramod, G.*, et al.* (2009) Estimating the Worldwide Extent of Illegal Fishing. *PLoS ONE* 4, e4570.

Findings

The study of studies found that studies to estimate IUU catches range in geographical scope from those concentrating at very local levels, through national and regional studies, to those attempting to estimate IUU catch at a global level. The sub-global estimates cannot be combined to generate a global estimate as they do not cover all fisheries or ocean areas, tend to focus on marine industrial IUU fishing (and often of foreign fleets), in some cases overlap in geographical coverage (but with different estimates of IUU catch being produced), and use different methodologies which are not comparable.

With respect to a number of studies providing global estimates, these tend to have especially high levels of uncertainty over the estimates produced, because as the scale of these studies increases, they either lose accuracy or lose granularity because of the assumptions that they have to make for elements for which there are no data.

A number of global (or regional) studies estimate 'missing or unknown catch' rather than catch that is specifically IUU. This is important as such studies have a limited biological focus/objective, which while of benefit, fails to recognize that IUU fishing is also an economic and social problem, with economic and social impacts not just biological ones in terms of impacts on fish stocks and the reliability of stock assessments based on known catches.

The inclusion of different aspects of illegal, unreported and unregulated fishing in the estimates are not consistent, nor is the definition of IUU fishing in the IPOA-IUU consistently applied. The studies demonstrate considerable confusion about what illegal catch is, what unreported catch is, and what unregulated catch is, often grouping unknown catches under a single IUU umbrella.

The studies use a wide range of different sources of information including: surveillance data and compliance levels; remote sensing (e.g. VMS, AIS); logbooks; expert judgment based on experience; interviews with fishermen and enforcement agencies; observer data; onboard cameras; stock assessment models; and trade data. These sources of information have different uses in terms of different methodologies used to generate estimates of different aspects of illegal, unreported, and unregulated fishing activity, for example of unknown IUU catch for known vessels, of unknown catch of unknown/unseen vessels, or of catch volumes which are known but which might nevertheless be illegal. The study of studies concluded that most of the methods used have limitations. For example, they may be very good at estimating all the unreported catch of a particular species, but less good at identifying where it came from or what types of IUU were being used. Or they may be very good at identifying specific violation types, but poor at estimating quantities. Or they may estimate IUU catch of target species but have no estimate of the impact of IUU fishing on other species.

The study of studies also found that many of the studies are insufficiently transparent about the sources of information and weaknesses in the methods used, and make a large number of assumptions which lead to inevitable questions over the accuracy of the estimates produced.

Conclusions

The study of studies recognizes that there may be some political support for an updated global estimate of IUU catch, and for FAO to be involved in its preparation given FAO's global mandate for fisheries. However it notes that the importance of combatting IUU fishing is now widely recognized at the global level suggesting that the advocacy benefits of a global estimate may be limited. Advocacy benefits may also be diminished due to wide confidence intervals and the likely inherent technical weaknesses in the accuracy of any global estimate; from a technical perspective a global estimate may serve little benefit and not be advisable. The technical guidelines on methodologies for estimating (global) volumes of IUU catch suggested by the workshop in Rome in 2015 might nevertheless be useful in improving the quality of studies being completed at local, national or regional levels.

In terms of contributing towards efforts to combat IUU fishing and reduce levels of IUU catch, of potential benefit could be the development of technical guidelines on how to conduct risk-based assessments of IUU fishing. A number of frameworks for IUU risk assessments are being used by RFMOs and national administrations. But as the 5th GFTEW in Auckland observed in March 2016, there is currently no guidance on how to complete such assessments, and many developing and developed countries alike would benefit from technical guidance. The completion of IUU risk assessments could also, but need not necessarily, result in and be the basis for estimates of IUU catches and further consistent monitoring of evolution of IUU catches. The first step in developing such technical guidelines would be the preparation of an inventory and review of all existing risk assessment frameworks in use.

Indicators of IUU fishing to monitor progress in combatting IUU fishing are critically important but from a technical perspective need not include a global estimate of IUU catch as levels of accuracy and large differences between upper and lower estimates would mean that it would be difficult to statistically demonstrate any difference between global estimates prepared at different intervals. The problem of comparison would be compounded if methodologies were changed or improved between global estimates prepared at intervals. Indicators could thus focus on other aspects such as numbers of vessels on IUU fishing vessel lists, number of countries issued with 'yellow' and 'red cards' under the EU IUU regulation, the outputs of IUU risk-based assessments, and perhaps some specific regional or local estimates of IUU catch in high risk areas based on repeatable and robust methodologies. However more consideration needs to be given as to whether it is advisable to have a single indicator of IUU fishing, or whether a 'suite' of indicators might be more beneficial and if so what should be included.

Recommendations to COFI

Noting that COFI has not earlier endorsed the suggestions of the 2015 Rome workshop, the findings of the study of IUU studies, or the deliberations of the 5th GFETW, the study of studies recommends that COFI consider and advise FAO on whether:

(i) an updated global estimate of IUU catch is desirable and if so what would be its objective and what role FAO should have in supporting/developing such an estimate.
(ii) FAO should lead a process to develop technical guidelines to improve the quality of studies completed at local, national and regional (and potentially global) levels to estimate IUU catch, and whether such guidelines should revisit the IPOA-IUU definitions, not necessarily departing from them but identifying separate categories of IUU that should be considered in risk assessments and monitoring studies that are more attuned to current experience and practices.
(iii) FAO should support the development of technical guidelines on conducting IUU risk-based assessments.
(iv) reporting globally on indicators of IUU fishing would be beneficial, and if so what the process should be for proposing, agreeing and reporting on such indicators, and what role FAO should play in such a process.

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Acronyms

AIS	Automatic Identification System
CMM	Conservation and Management Measure
CCRF	Code of Conduct for Responsible Fisheries
CDS	Catch Documentation Schemes
COFI	Committee on Fisheries
CPUE	Catch Per Unit of Effort
EEZ	Exclusive Economic Zone
ETP	Endangered, Threatened and Protected (species)
EU	European Union
FAD	Fishing Aggregating Device
FAO	Food and Agriculture Organisation (of the United Nations)
GFEFW	Global Fisheries Enforcement Training Workshop
GR	Global Record
ICES	International Council for the Exploration of the Seas
IMCS	International Monitoring Control and Surveillance (network)
IPOA-IUU	International Plan of Action – Illegal, Unreported and Unregulated (fishing)
IUU	Illegal, Unreported and Unregulated (fishing)
MCS	Monitoring, Control and Surveillance
RFMO	Regional Fisheries Management Organisation
SAR	Synthetic Aperture Radar
SOFIA	State of World Fisheries and Aquaculture
UN	United Nations
UNFSA	United Nations Fish Stocks Agreement
UVI	Unique Vessel Identifier
VMS	Vessel Monitoring System
WCPFC	Western Central Pacific Fisheries Commission

1 CONTEXT, OBJECTIVES, AND METHODOLOGY OF THIS STUDY

1.1 BACKGROUND TO THIS STUDY OF STUDIES

FAO has played an active role internationally over many years in efforts to combat Illegal, Unreported and Unregulated (IUU) fishing. These actions, guided by the Committee on Fisheries (COFI), and have resulted in amongst other things: the UN Fish Stocks Agreement; The Code of Conduct for Responsible Fisheries; the FAO Compliance Agreement; the IPOA-IUU; the Port States Measures Agreement; Voluntary Guidelines on Flag State performance; and ongoing work to establish a Global Record of fishing vessels, and Unique Vessel Identifier (UVI). An International Monitoring Control and Surveillance (IMCS) Network was also established in 2001 to link fisheries enforcement agencies and MCS practitioners from around the world and to facilitate increased communication and information sharing to prevent, deter and eliminate IUU fishing. The network is a voluntary organisation acting informally, and while its members participate in an individual capacity rather than formally representing their international, regional or Member State organisations, it serves to share experiences, methods and tools for combatting IUU fishing.

FAO and other international partners have also been active in regional forums to combat IUU fishing. Regional Fisheries Management Organisations have adopted a wide range of Conservation and Management Measures (CMMs) aimed at reducing IUU fishing, a range of catch documentation schemes (CDS), lists of IUU fishing vessels, and many Compliance Committees within RFMOs increasingly serve to report on IUU issues and related CMMs. At the regional level RFMOs are engaging more collaboratively than ever before with a wider range of other organisations (such as INTERPOL's Environmental Security Unit) to combat IUU fishing. The European Union has also adopted a regulation aimed at combating IUU fishing for fisheries under its competency as coastal state, flag state, port state and market state.

The increasingly robust international and regional framework aimed at combatting IUU fishing has also translated into considerable efforts at national levels to reduce IUU fishing.

Given this rising international concern of IUU as reflected by such action mainly since the mid 1990s and early 2000s, a number of studies began to attempt to measure and report on the extent of the IUU problem. Perhaps the most widely quoted one is a study completed by David Agnew *et al* in 2009 (Agnew, D., *et al*, 2009) titled "Estimating the Worldwide Extent of Illegal Fishing". This study estimated that IUU-caught fish in 2003 was 11-19% of reported catches representing 10-26 million tonnes of fish valued at US$10-23 billion.

In February 2015, FAO, with support from Pew Charitable Trusts, convened a workshop in Rome, Italy, to develop a methodology to estimate IUU fishing at global level. The motivation for this workshop reflected a recognition that the Agnew study is now outdated both in terms of the 2003 estimate it provided and the very different international, regional and national context now influencing levels of IUU fishing as represented by the actions outlined above. While the 2009 study was innovative for its time in generating a global estimate, the wide range of studies that it used as source information, which estimated different elements of IUU and with varying confidence, led to the study generating a wide range between the upper and lower estimates. Furthermore the study examined the situation as it existed in the mid-2000s, some 10 years ago. FAO therefore considered that it might be timely and appropriate

to have a new global estimate of IUU fishing, both to serve an advocacy purpose in mobilizing further action to combat IUU fishing, and to assess change in IUU fishing since 2003.

There were three main conclusions of the 2015 workshop in terms of what FAO could do. First was for FAO to coordinate a Study of IUU fishing studies, to review the different methodologies and document the different studies available. Second was for FAO to lead a process to develop technical guidelines for future studies so they could be conducted in a way that allowed for their estimates to be combined with those of others to contribute to a global estimate. Finally it was proposed that FAO could consider a suite of indicators of IUU for inclusion in FAO's bi-annual flagship publication 'the State of World Fisheries and Aquaculture'.

The Study of IUU fishing studies was considered important by the workshop as a first step to be taken by FAO, because the workshop was informed about: (i) different ideas commonly held about how IUU fishing should be defined, what a definition of IUU fishing should include, and therefore what studies to estimate IUU fishing should attempt to quantify; (ii) a number of completed or ongoing/planned studies to estimate the extent of IUU fishing in certain regions, most of which were using different methodologies; (iii) a wide range of methodological options and data sources for estimating IUU fishing.

1.2 OBJECTIVES OF THIS REPORT

The purpose of this report is to provide relevant information to COFI on the issue of having a new global estimate of IUU fishing, and takes as its starting point the fact that:

1. the Rome 2015 workshop did not represent a formal mechanism with the power to instruct FAO.
2. COFI has not previously asked FAO to develop a global estimate of IUU fishing.
3. COFI should guide FAO's activities on estimating and reporting on levels of IUU fishing.

The objectives of this study of studies and this report are therefore to:

1. Identify ongoing or recently completed studies to estimate levels of IUU fishing.
2. Analyse and categorize the different studies based on the methodologies used and the different aspects of IUU fishing included in the studies.
3. Assess the methodological strengths and weaknesses of the studies.
4. Consider how comparable the studies might be and how possible it might be to combine their outputs into a global estimate of IUU fishing (noting that this report itself is not intended to produce a global estimate).
5. Provide recommendations to COFI on the usefulness and feasibility of having a new global estimate of IUU fishing, and on FAOs role in contributing to such a global estimate and in guiding countries on how to estimate IUU fishing.

Additionally, while not a primary objective of this report, given the recommendation of the Rome 2015 workshop on indicators, this report also provides some comment for COFI on the

issue of indicators of IUU indicators outside of a single global estimate. Indicators of IUU fishing at national, regional and international level are potentially important in terms of:

1. Sustainable Development Goal number 14 "Life below the water" and the related target of effectively regulating harvesting and ending IUU fishing by 2020.

2. Mobilising further action to combat IUU fishing.

3. Reporting on progress in reducing IUU fishing.

1.3 METHODOLOGY USED DURING THIS STUDY

The approach taken to completing this study of studies involved a number of steps.

A kick off meeting was held with FAO staff in Rome in December 2015 to discuss the scope of the study, and it was agreed that:

- the studies to be included in the review should primarily include those published since 2009 but could include some older studies where they are considered of special relevance;
- studies reviewed would not include reports of specific IUU fishing events and the volumes of IUU fish resulting from those events, but would rather focus on studies that estimate levels of IUU fishing at a broader fishery or geographical level;
- likewise methodologies would be reviewed for studies *estimating levels of IUU fish catch*, not those that report on or estimate compliance levels (noting that compliance levels may be used in studies to estimate IUU fish catch); and
- sources of information used to estimate levels of IUU fishing (i.e. inspection data, compliance records) should not be considered as *studies* of IUU fishing (even though they are frequently used in studies to estimate levels of IUU catch).

It was also agreed at the kick off meeting that the outputs of the study of studies would the form of three main deliverables, all of which should be available for the COFI 32 session in July 2016: (i) a contribution to a COFI "working document" on IUU fishing; (ii) a short one to two page "information document" summarizing the study of studies; and (iii) the main report (this report) to be made available as a "session background document" for the COFI meeting.

Relevant studies were then collected using literature searches for relevant peer-reviewed articles published in scientific journals, web-based searches were used to collect project reports and other relevant studies, requests were made via FAO to RFMOs for relevant studies, and Poseidon used its global network of contacts to identify relevant studies. In addition, the authors of this report participated in the 5th Global Fisheries Enforcement Training Workshop held by the IMCS network in Auckland, New Zealand in March 2016. This participation afforded the opportunity to engage with more than 150 MCS practitioners from around the world and to request relevant studies.

A total of 89 studies, journal articles and research reports were collected and reviewed.

Forty-four studies (see Appendix 1) were studies falling within the scope as detailed above and estimated levels of IUU fish catch. For each of these a summary fiche of half to one page was prepared to capture key information for aspects such as: the study's geographical scope; the fisheries being covered; the objectives of the study; the main methodology; the data

sources; the strengths and weaknesses; and the studies replicability and compatibility with other studies. These summary fiches provide a record of the different studies which may be of use and relevance to others, and so are included in this report in Appendix 3.

An additional 35 studies/reports/articles (see Appendix 2) were also reviewed, but were found to fall outside the scope as detailed above. Mostly this was because the studies reported on compliance or incentives for IUU fishing rather than estimating IUU fish catch. For each of these studies, Appendix 2 provides a short note under each reference as to the main reason why it falls outside the scope of this review and therefore why a fiche has not been prepared.

The summary fiches were then analysed to draw out key findings, conclusions and recommendations for COFI.

A second visit by the consultants was made to FAO prior to the finalisation of this report to present to staff in the Fisheries and Aquaculture Department the main findings, conclusions and recommendations. Comments made at the meeting were incorporated into this report.

1.4 THE DEFINITIONS OF IUU FISHING

While later text in this report discusses the coverage of different studies and their focus on different aspects of illegal, unreported, and unregulated fishing, the definitions of these different components in the IPOA-IUU are such that:

Illegal fishing (Articles 3.1.1 - 3.1.3 of the IPOA-IUU) refers to fishing activities:

> 3.1.1 conducted by national or foreign vessels in waters under the jurisdiction of a State, without the permission of that State, or in contravention of its laws and regulations;
>
> 3.1.2 conducted by vessels flying the flag of States that are parties to a relevant regional fisheries management organization but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international law; or
>
> 3.1.3 in violation of national laws or international obligations, including those undertaken by cooperating States to a relevant regional fisheries management organization.

Unreported fishing (Article 3.2.1 - 3.2.2 of the IPOA-IUU) refers to fishing activities:

> 3.2.1 which have not been reported, or have been misreported, to the relevant national authority, in contravention of national laws and regulations; or
>
> 3.2.2 undertaken in the area of competence of a relevant regional fisheries management organization which have not been reported or have been misreported, in contravention of the reporting procedures of that organization.

Unregulated fishing (Article 3.3.1 - 3.3.2 of the IPOA-IUU) refers to fishing activities:

> 3.3.1 in the area of application of a relevant regional fisheries management organization that are conducted by vessels without nationality, or by those flying the flag of a State not party to that organization, or by a fishing entity, in a manner that is not consistent with or contravenes the conservation and management measures of that organization; or
>
> 3.3.2 in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law.

The first set of definitions under 'illegal fishing' are those most usually associated with "pirate" fishing – fishing without a licence – but also cover all other elements of non-compliance with national and international laws – for instance fishing in closed areas or seasons, with prohibited gears, or catching over prescribed quotas. In all these cases non-compliance may result in the quantity of catch being known, but it may also not be known.

The second set of definitions under 'unreported fishing' attempts to be very specific about the loss of information on catch quantity arising from non-compliance with reporting requirements, but does not cover the non-reporting or misreporting of catch in the situation where reporting is required by national law or covered by the reporting procedure of an RFMO. This has led to much confusion in IUU studies (see further discussion in Section 2.1 below), since in many cases a missing catch volume can be identified but its legality or otherwise is not known. Many countries, for instance, do not have regulations requiring recording of discards, self-consumption or recreational fishing catches, and in some cases quota-based regulations accidentally encourage discarding without requiring its reporting.

Recent international instruments, such as the Port States Measures Agreement and the FAO Voluntary Guidelines on Flag State Performance essentially adopt or assume these IPOA-IUU definitions.

However in establishing IUU vessel lists, RFMOs contribute to the definitions of IUU fishing with binding measures being associated with vessel listing and de-listing criteria. These listing criteria are not necessarily fully aligned in practice with the IPOA-IUU definitions, and not uniform across all RFMOs - indeed within a specific RFMO the definitions may not be similar for contracting parties and cooperating non-contracting parties on the one hand, and non-contracting non-cooperating parties on the other hand.

While it is not the objective of this review to analyse the definitions of IUU fishing in Member State legislation, it seems likely that the specific definitions being used, may also differ. The definition of IUU fishing may be dealt with directly in Member States' legislation, indirectly through references to a binding measure of a RFMO, or through a combination of both. And these definitions may thus be based on a combination of the definitions in the IPOA-IUU, those adopted in practice by RFMOs, or Member State's own interpretation of what constitutes IUU fishing. Further issues associated with the definition of IUU fishing arise from the application of the EU IUU Regulation, with measures included in yellow and red-card notifications under the Regulation going beyond the definition of IUU fishing contained in the Regulation.

2 FINDINGS FROM THE REVIEW OF STUDIES ESTIMATING IUU FISHING

2.1 THE INCLUSION OF I, U, AND U IN THE STUDIES

As noted above, this study of studies has reviewed the methodologies used in 44 studies which made estimates of IUU fishing. The studies reviewed have a wide range of different objectives in terms of estimating different components of IUU fishing activity (see Section 2.3), generally stating the IUU behaviours they seek to estimate but only sometimes specifying the types of IUU activity estimated in respect of the IPOA-IUU definition; and rarely are the methods consistent between studies (see Section 2.2).

The largest body of work using one consistent methodology is the catch reconstruction methodology developed by Pitcher *et al* (2002) and Pauly and Zeller (2015), but these studies usually do not explicitly separate between reporting errors that fall within the IPOA-IUU definition and those that do not (see Section 2.1). A number of studies aiming at reconstructing catch statistics include under the IUU umbrella some specific activities which, arguably, are not explicitly considered by the IPOA-IUU because they do not infringe existing laws or regulations. A frequent example is the inclusion under 'IUU' fishing of catches discarded at sea or any other sources of unmeasured catches like subsistence catches, bait usage or recreational catches, with the difference between reconstructed catches and official catches being termed as IUU e.g. Lescrauwaet *et al*. (2013), Pham *et al*. (2013), Coll *et al*. (2014). Some studies aiming at the same catch reconstruction objective include similar sources of unreported catches but more correctly do not use the IUU acronym in any part of their studies (e.g. Tesfamichael and Pitcher (2007) or Al-Abdulrazzak *et al*. (2015)) to qualify the difference between their reconstructed catch estimates and official catch data.

For some studies, definitions are overlapping. For example, estimates of unreported catches by duly licensed vessels in contravention with legal reporting requirements (thus mostly FAO IUU definition 3.2.1, see for example Aanes *et al*. (2011) or Hendati-Sundberg *et al*. (2014)) do not identify whether underreported catches have been obtained in compliance or in breach with existing technical regulations (gear specifications, closed season, closed area), thus incorporating an element of FAO IUU definition 3.1.1. Other studies do not clearly separate estimates of underreporting by legal vessels from underreporting by vessels operating illegally, while stating that they are unable to make the distinction (Agnew *et al*. (2009), Clarke *et al*. (2006) , Clarke *et al*. (2009) or Pramod *et al*. (2014)). Therefore, most studies aiming to estimate real catches from a given set of fisheries focus on a grouping of Illegal and Unreported components, some explicitly excluding the Unregulated component, others not.

Another example of overlapping definitions includes the recent FFA study (MRAG, 2016) study which clearly identifies different types of IUU behaviours subject to estimates, but with definitions deviating from IPOA-IUU definitions. For example, the unlicensed/unauthorised fishing infringement type in the FFA study that is subject to a specific estimate amalgamates elements of illegal fishing and unregulated fishing.

Nonetheless, the studies reviewed do also contain some that concentrate on particular types of IUU fishing that are well aligned with the IPOA-IUU definitions. Studies estimating unregulated catches of non-party vessels in RFMO areas are focused on this particular type

of IUU behaviour (FAO IUU definition 3.3.1) and do not include any other behaviour falling under other IPOA-IUU definitions (Agnew (2000), Agnew and Kirkwood (2005)).

The difficulties encountered by the different studies in providing consistent definitions of IUU fishing that are unambiguously aligned with IPOA-IUU definitions can be explained by the lack of clarity of those definitions in the IPOA-IUU, and a lack of alignment of those definitions to the types of activities, and quantities (catch; economic loss) estimated in typical IUU studies. As noted by Tsamenyi *et al*. (2015), the IUU fishing term is broad and, due to the diversity in governance frameworks, national legislation, fishing operations throughout the globe, and RFMO conservation and management measures, there are a number of grey areas and overlapping situations among the three components of IUU fishing.

In addition, whilst the IPOA-IUU describes a number of illustrative activities under each of the IUU fishing components, it does not completely cover all possible scenarios and does not address the issue of overlap among the three IUU fishing components, leaving open some room interpretation. The categories also do not line up well with either a general understanding of the types of problems or the egregiousness of problems; for instance, 3.1.1 covers both (i) unlicensed fishing by large industrial vessels in State waters off west Africa and (ii) using illegal gears. And the IPOA-IUU fails to emphasise sufficiently the importance of controlling transhipment as a form of illegal fishing activity.

In response to such problems Tsamenyi *et al*. (2015) proposed a categorisation of IUU behaviours which would place all misreporting in contravention with existing laws or regulation under the illegal component of IUU, and leave under the underreported component reporting that is not required by a law or regional/international conservation and management measure, like for example unreported discards where such reporting is not mandatory. Unregulated fishing under the proposals made by Tsamenyi *et al*. (2015) would be largely an issue of governance. These proposals have not been endorsed by FAO or the wider international community, but there are good arguments for the definitions in the IPOA-IUU to be revisited.

2.2 THE GEOGRAPHICAL AREA, SCALE AND SCOPE OF THE STUDIES

While the lists of studies in Appendix 1 and Appendix 2 may not be completely comprehensive, the studies listed in Appendix 1 and their respective fiches in Appendix 3 allow for some findings as to the coverage of studies estimating levels of IUU fishing in terms of their geographical scale, the ocean areas they consider, and the types of fishing fleets, gear and species which are included.

Based on fiches presented in Appendix 3 and as shown in Table 1:

- It is most common for the studies reviewed to focus on regional, or national IUU fishing issues, rather than on global or local/sub-national estimates;
- Very few (2 [5%] of the 44 studies) examine IUU fishing in inland freshwater fisheries (in rivers or lakes), even though inland fisheries accounted for 12.5% (11.7 million tonnes) of total global capture fisheries production in 2013 of 93.8 million tonnes[2];

[2] FAO FishStatJ

- There is a strong concentration of the studies on the Pacific Ocean (or parts of it) with the Pacific being the subject of 18% of the studies reviewed, but given that the Pacific accounts for more than 50% of global catches this region may still be considered under-represented in terms of studies to estimate IUU fishing;
- The East and West Atlantic regions combined accounted for 21% of global catch in 2013, and 18% of the studies reviewed are concerned with estimating IUU fishing in this Ocean;
- Seemingly also over-represented in terms of the focus of studies, is the Antarctic which was the subject of 7 (16%) of the studies reviewed, but only accounts for <0.5% of global catches in volume terms.
- Only two studies were estimates of IUU fishing in the Americas, one a study of commercial and recreational fisheries targeting groundfish and salmon in British Columbia, and the other a study of IUU fishing in the Mexican EEZ. It is not clear whether the small number of studies focussing on this continent is due to studies not being published in English and therefore not being collected by the consultants, or whether the Americas are actually under-represented in terms of studies estimating levels of IUU fishing.

Table 1: Geographical scale and ocean coverage of studies to estimate IUU fishing

Scale / Ocean areas	global	local / sub-national	national	regional	Total	%
All	6			2	**8**	18%
Antarctic / S Oceans				7	**7**	16%
Artic				1	**1**	2%
Baltic			1	1	**2**	5%
East Atlantic Ocean		2	3	2	**7**	16%
Indian Ocean			3	3	**6**	14%
Inland rivers/lakes		1		1	**2**	5%
Mediterranean		1		1	**2**	5%
Pacific Ocean		4	3	1	**8**	18%
West Atlantic Ocean			1		**1**	2%
Total	**6**	**8**	**11**	**19**	**44**	
%	14%	18%	25%	43%		

Source: Poseidon analysis of studies reviewed. Notes: (i) Not all global studies make estimates of total global IUU fish catch, as some make estimates of global IUU catch of particular species or by particular fishing fleets. (ii) Studies with a regional geographical scale but which cover all ocean areas are studies using a number of regional case studies in different oceans.

Table 2 below shows that in terms of the species groups that are covered by the studies, many (17, 40% of the studies reviewed) cover all species within the geographical area that is the focus of the particular study. Twenty-seven (61%) of the studies reviewed focus on one particular species or species group, although few of these had crustacea, freshwater fish, cephalopods, or other molluscs as the focus of their estimates even these species groups accounted for 7%, 12.5%, 4% and 3% respectively in 2013[3] i.e. a total of almost 30% of the

[3] FAO, FishStatJ

volume of global catches. Some of these species can be very susceptible to overfishing due their biological characteristics, and of high value, making a lack of focus on such species surprising.

Table 2: Types of species covered in studies to estimate IUU fishing

Species	Total	% of Total
All (in the area being covered by the study)	17	39%
Anadromous	2	5%
Crustacea	1	2%
Demersal	9	20%
Freshwater	1	2%
Mollusc	1	2%
Multiple	6	14%
Pelagic	7	16%
Total	**44**	

Source: Poseidon analysis of studies reviewed. Notes: studies focussing on anadromous species both concerned salmon, while the study related to molluscs estimated IUU fishing for abalone.

Table 3 below categorises the different studies reviewed in terms of their focus on IUU fishing by different types of fishing fleets and gears. Most studies (32, 73%) consider all gear types in the area that is the focus of the study, but a few studies (12) estimate IUU fishing specifically for gillnets, longlines, pots/traps, or trawling. Seventeen of the 44 studies (39%) estimate IUU fishing as it pertains not just to commercial fishing but also to recreational and/or subsistence fishing – these studies are those making estimates of 'total removals' (see more discussion below in Section 2.4), with 27 being concerned only with commercial fisheries. Of the studies making estimates of IUU fishing in commercial fisheries, while 11 include all fleet types, 14 focus on large-scale/foreign fleets, and only two focus solely on IUU fishing by small-scale fleets - this despite the fact that small-scale fisheries employ around 90% of the world's fishers and fish workers[4] and make a significant contribution to global catches.

[4] FAO, http://www.fao.org/3/a-au832e.pdf, http://www.fao.org/3/a-i4356e.pdf

Table 3: Types of fishing fleets and fishing gear covered in studies to estimate IUU fishing

Gear type / Fleet type	Gillnet	Longline	Multiple gears	Pots/traps/ divers	Trawling	Total	%
commercial, recreational and subsistence fisheries			11			**11**	25%
commercial and recreational fisheries			5	1		**6**	14%
all commercial fleets		1	9	1		**11**	25%
foreign fleets only			2			**2**	5%
large scale fleets only	2	3	4		3	**12**	27%
small-scale fleets only	1		1			**2**	5%
Total	**3**	**4**	**32**	**2**	**3**	**44**	
%	7%	9%	73%	5%	7%		

Source: Poseidon analysis of studies reviewed. Notes: studies covering 'gillnet', 'longline', etc. estimated IUU fishing for that particular gear type only.

For studies concerned with different oceans, geographical scales, fleet types and gears, there is no clear pattern or consistent use of a particular type of methodology (as discussed further in Section 2.4), or indeed a focus of the studies on different aspects of I,U and U (as discussed in Section 2.3) i.e. studies focussing at the national level, or on pelagic fisheries, for example, don't all use the same methodology or consider/include the same types of I, U and U. This fact, coupled with the discussion on the partial coverage of the studies as presented above also makes it clear that the sum of all IUU fishing estimates made by the individual studies at local, national and regional levels would be far from complete in terms of global coverage, would result in some double-counting which would be difficult to unpick, and could not be compiled into a global estimate.

2.3 THE MAIN OBJECTIVES OF THE DIFFERENT STUDIES

Many of the studies to estimate IUU fishing start by clearly articulating their objectives, and these often relate to the components of IUU behaviours being estimated, the geographical scale of the studies, the focus on aspects of IUU behaviour, and the species, fleet and gear types to be included. The objectives often have a strong bearing on the methodologies then used.

More than a quarter of the studies reviewed (e.g. Ainsworth *et al*, 2005, Zeller *et al* 2011, Belhabib *et al* 2014, Swartz *et al* 2014, Al-Abdulrazzak *et al* 2015, Pauly and Zeller, 2016, to name a few) have as an objective the estimation of 'total removals' i.e. the objective is to obtain a truer picture of the impacts of catches on sustainability, and the methodology used is to re-construct catches (often adding recreational and subsistence catches to known commercial catch). These studies (which examine total removals at a range of different geographical scales) often therefore focus strongly on 'unreported' catches, but as already noted only some of these are likely to be IUU as defined by IPOA IUU definition 3.2.1 or 3.2.2. Indeed, these studies are less concerned about the cause of unreported/misreported catch than its magnitude.

The objective of some studies is to focus on a particular species and just to raise awareness of levels of IUU catch, and this can allow for the use of specific methodologies appropriate for those species. For example, trade data are used when considering IUU catches of shark (Clarke *et al*, 2006), salmon (Clarke *et al*, 2009), tunas (MRAG, 2016) and orange roughy/abalone/sea cucumber (Willock *et al*, 2004).

For other studies, their objective in estimating levels of IUU catch is strongly underpinned by the desire to *use* those estimates to make recommendations about necessary management actions to reduce IUU fishing. In such cases this objective can impact on the geographical scale adopted by the study and the species covered so as to match the scope of analysis to the management competencies of different organisations and institutions. Thus the recent FFA study (MRAG 2016) quantified IUU volumes and values of tuna by fleet segment in areas under the management competency of the WCPFC so to as make data available to the WCFPC in the hope that such data will be used by the Contracting Parties to take necessary management action. Another very recent study of IUU fishing in the Asia-Pacific region (Funge-Smith *et al*, 2015) also had as a key objective the identification of IUU hotspots in order to inform a discussion about opportunities to combat IUU fishing by countries in the region, even providing an IUU risk assessment tool. Other studies at a national or sub-national level, for example Glazer *et al* (2015) when estimating IUU fishing in Somali waters, and Wagey *et al* (2009) providing estimates of IUU activities in Indonesian waters, are also intended to focus the attention of management authorities on necessary management action to reduce IUU fishing. Many of the studies reviewed but for which fiche have not been prepared (i.e. those in Appendix 2) have an especially strong focus and objective on identifying necessary management and MCS actions to reduce IUU fishing, given that they tend to focus on compliance.

A sub-objective of many of the studies, whether they focus on estimating total removals and/or on identifying potential management measures to reduce IUU fishing, is to identify the *drivers* of IUU fishing. These drivers are revealed to include economic incentives/benefits of IUU behaviour by fishers, macro-level economic and political factors, and weak fisheries management and related MCS.

2.4 THE DIFFERENT METHODOLOGIES USED BY THE STUDIES

The section considers in more detail the specific methodologies used to estimate IUU fishing and the building blocks or types of data/information that are often used in the studies.

Sub-national, national and regional studies

Methods giving estimates specific to defined IUU categories (see Section 1.4) can be used for different elements of IUU behaviour, and draw on a number of sources of information and data as building blocks to arrive at the final estimates. It should be noted that rarely does one study use an identical method as another study, and often studies use a combination of methods. This variability reflects the availability of data to different studies, and the fact that by the very nature of the problem IUU studies are trying to estimate unknown quantities, so researchers usually use methods that are tailored to their specific situations.

1. Quantity of unknown catch for unlicensed fishing (IPOA-IUU definition 3.1.1) or unregulated fishing (definition 3.3.1) i.e. ***activity of unseen or unknown IUU vessels or***

fishers can be estimated from the estimated number of vessels/fishers fishing without a licence or in an unregulated way multiplied by the estimated catch per vessel/fisher.

- Estimated unseen fishing effort - number of vessels or fishers fishing - may be acquired from surveillance overflight data (eg MRAG, 2016), remote sensing (e.g. comparison of AIS/VMS/SAR data), MCS surveillance and arrest data, expert judgement, or identification of specific IUU vessels and knowledge of their whereabouts and catch per day (e.g. Coalition of Legal Toothfish Operators, (2015)). Surveys of active or discarded fishing gear (Agnew & Kirkwood 2005; Kleiven et al. 2012; Williamson et al. 2014). In all cases, estimates must take into account observation efficiency and avoidance probability in order to obtain a useful estimate of overall unseen effort.

- Estimated catch per vessel or fisher or gear unit is often assumed to be the same as legal fishing with like gear, target, area, and may include bycatch rates of endangered, threatened and protected (ETP) species; sometimes estimates are made based on the number of likely trips, hold capacity, and catch rates of vessels, again based on legal vessels, or if there are no legal vessels operating in the area, expert judgement or knowledge of the specific characteristics of the fleet.

2. Quantity and type of ***unknown IUU catch from known vessels*** (vessels not complying with regulations) (illegal behaviour, misreporting or discarding; definitions 3.1.2, 3.2.1, 3.2.2) can be estimated from the estimated number of fishing vessels displaying the behaviour multiplied by the estimated discard or unreported catch per illegally behaving vessel.

    - Estimated number of vessels from known licence data expected to be undertaking transgressions, is usually obtained from a combination of licence records and surveillance data (e.g. surveillance reports provided by control authorities)

    - Estimated unreported or misreported catch in illegally behaving vessels is usually obtained from logbook or observer data from vessels that are known to be behaving legally, for instance when they have an observer/camera on board.

        - Observer data and comparative analysis between observed/unobserved trips (often using sophisticated statistical modelling techniques, eg Hentati-Sundberg et al. 2014) in situations where unexplained differences can be attributed to the adoption of illegal (e.g. illegal discarding, illegal shark finning);

        - Logbook data and comparative analysis can be used between expected legal vessels and others; and

        - Interviews with fishers or MCS professionals can provide anecdotal information on quantities and trends of illegal fishing, categorised by IUU type.

- It should be noted that where discarding is not illegal, good estimates of discarding are often available through observer data, but this does not contribute directly to IUU catch information.

3. ***Unknown catch generally***. Without any external reference points (such as a number of known vessels engaged in IUU behaviours as in (2) the quantity of unknown catch can still be estimated, but its origin is often unknown – whether it is illegal or not illegal based on the definitions in the IPOA-IUU (for instance discarding and reporting discard quantities is rarely illegal, even though it is assumed by many to be IUU). Techniques include

   - Using stock assessment models to estimate the total catch of a species, which when compared with declared catch provides an estimate of undeclared catch (which may not be illegal if it is estimated as discarded or unreported). This method has some similarities with the cross-comparison of observed/unobserved vessels, in that some known data are used to statistically infer unknown data. This is not the same as the non-statistically based inferences in the "anchors and influences" meta-methods discussed below, where unknown catches are inferred from changes in management regimes and assumed fisher behaviour, without an underlying statistical model such as a fish population model/stock assessment.

   - Using trade data and other combinations of high level statistics (landings; catches; imports; exports; transhipments) to estimate total catch or traded volumes, which when compared with declared catch provides an estimate of undeclared catch. Catches may or may not be illegal. For instance, Clark (*et al*, 2009) was able to attribute unreported salmon detected using trade data as illegal, but her similar analysis of shark catches (Clark 2006), and those made by Worm *et al* (2013) were simply estimates of total shark unreported catches, including mortality due to finning, which is both illegal and legal in various jurisdictions.

4. Quantity and type of ***IUU fishing that does not result in unreported catches*** can only really be obtained from MCS or remote sensing techniques. For instance, in tuna fisheries there is a growing interest in using camera technology to monitor all activities of vessels (setting FADs, hauling fish, fish size and species) and many companies are now offering these services (Archipelago Marine; Digital Observer Services to name but two).

Agnew (2015) characterised and provided strengths and weaknesses of the different data types/sources and their use in estimating different aspects of IUU behaviour, as shown in

Table 4 below.

Table 4: Strengths and weaknesses of common approaches to estimate IUU fishing at a case-specific level

Data type/source	Potential elements being estimated	Strengths	Weaknesses
MCS inspection data, from nominated patrol vessels and work by authorities at landing sites/ports	• Accurate recording of individual violations (IUU or non-IUU) in practice on land and sea	• High resolution data attributing IUU catches to actual fishing activity and violation type • Large sample sizes from fishery surveys may be statistically unbiased • Possible information on damage to non-target species and habitats	• Underlying statistical framework unlikely to be appropriate when arising from targeted MCS activities (i.e. this produces over-sampling of high IUU problems; see Green and McKinlay, 2009) • Catches from different IUU activities may not be recordable by inspectors at sea
Remote sensing, including satellite, ship and air surveys, on-board camera monitoring.	• Estimates of number of vessels fishing without licences or in areas that are prohibited	• Possibility of repeat synoptic surveys, generating high quality statistical data • Offers the possibility of matching various data sources – anecdotal and objective. • Can detect and track individual vessels globally, not just in area of study	• Computationally and electronically intensive/expensive • Identification of actual fishing activity is lacking • Cannot detect non-positional violations (eg gear, misreporting, discarding) • Must be matched with other estimates of catch rate, species, etc from legal vessels
Stock assessments deriving estimates of missing catches	• Estimates of total unreported catches of target fish (the one that is the subject of the stock assessment) • May allow resolution by IUU type if input data allow.	• Statistically robust estimates • Good spatial and temporal coverage: coverage of the whole of the stock, over all years • Potentially applicable to all species caught by the fleet if they are assessed	• Usually unable to identify violation type, e.g. to separate illegal from legal unreported • Should be used in conjunction with other information on relative levels of IUU activity to anchor the estimates • Best to estimate significant periodic IUU, rather than long term constant IUU • No information on collateral damage by IUU fishing to non-target species and habitats

Data type/source	Potential elements being estimated	Strengths	Weaknesses
Trade data analysis, including data captured by catch and statistical documentation schemes	• Estimate of total unreported catch by species and sometimes by country	• Easy access to global data • Accurate data if declared on catch/import documents by all countries importing, or if all countries subscribe to the scheme • Comparison with reported catch means that estimates are illegal or unreported, but unreported may not be strictly illegal, depending upon circumstance	• Mis-declared products not captured • Usually limited to iconic species, which are declared on customs forms, or documents • Trade data not linked to catch documentation (which tracks catches through the entire supply chain) may suffer from low temporal resolution (product often stays in storage for months or years) meaning that cross checking with declared catch data is inaccurate • Where fish can be caught and landed in a number of jurisdictions identification of IUU location is difficult • Specific violations (except import violations) cannot be detected • Relies on exporting - cannot detect IUU where fish are consumed locally
Expert judgement	• Individual point estimates of IUU, or trends over time	• Integrates knowledge from practitioners, often fishers with direct knowledge of IUU activities, or MCS professionals	• Difficult to validate or understand in the context of any objective, comprehensive and statistical analysis. • May suffer from over-sampling – i.e. only those experiencing high IUU levels will be interviewed

Source: Poseidon, adapted from Agnew (2015)

All the methods in

Table 4 can provide estimates of "missing catch" but this may not be easily (or generally) expressed in terms of IUU unless their source data allows identification of IUU. For instance, an assessment method was used by International Council for the Exploration of the Seas (ICES) (ICES, 2014) to estimate "un-recorded" catches of cod. Instead of assuming catches to be known without error the assessment model used assumed that catches include observation noise. This has the consequence that estimated F-at-age paths display less inter-annual variability than with deterministic assessment models, because part of the observed fluctuations in catch-at-age are arising from observation noise instead of from changes in F. Application of the model assuming unknown catch observation noise for a very long period of time (1993 to the present) did not lead to satisfactory results, but constraining the "uncertain" time to 1993 – 2005 allowed ICES to estimate that during the period of most rapid management action, the early 2000s, real catches were up to 68% higher than the combined declared catches. This example displays two features. Firstly, assessment models usually need sufficient "contrast" to be able to estimate unknown catches, and this is best provided through assuming that IUU fishing occurred over a small discrete period of time within a longer period assessment. Secondly, ICES at this point did not know whether the unknown catches were discards (at that time not illegal, and therefore not IUU); or unreported (and landed) catches in contravention with mandatory reporting requirements (thus illegal). This level of resolution of the data can only be estimated through comparison with other data sources, such as MCS reports.

Most of the methods discussed above have very specific limitations. They may be very good at estimating all the unreported catch of a particular species, but less good at identifying where it came from or what types of IUU were being used. Or they may be very good at identifying specific violation types, but poor at estimating quantities. Or they may estimate target species IUU but have no estimate of the impact of IUU fishing on other species.

Global (and regional) estimates using meta-data

The studies using the methodologies discussed above all work at different scales - sub-national, national or regional. Integrated global (or in some cases regional) studies have tended to use meta-analyses – analyses or reviews of large amounts of secondary data and other studies completed at smaller geographical scales. The most common methodology used to pull these disparate studies and information sources together is the "anchor points and influence factors" method (Pitcher *et al*, 2002) which was used in the only global study to date (Agnew *et al*, 2009). This method uses some confirmed estimates of IUU or underreporting of catches, such as derived using the building blocks and methodologies discussed above for specific years, and extrapolates or interpolates these estimates to other species, years and fleets based on logical argument or other, often anecdotal or interview-based information. Uncertainty is often high, as represented by upper and lower bounds to the anchor data and to the interpolated data, from which an overall estimate of IUU catches or activity can be derived.

As the scale of these studies increases, usually they either lose accuracy or lose granularity because of the assumptions that they have to make for elements for which there are no data. For instance, there may be good data on illegal discarding or unlicensed fishing one year and no other estimate for a further 10 years; or there may be good data on unreported catches

of one species, but no knowledge of other species or the IUU status of those catches. Furthermore the opportunity for overlap between studies, leading to double counting, increases (for example, an individual instance of IUU behaviour might be estimated separately by an RFMO, by a flag state, or by a coastal state, and therefore could be counted twice (or more), or catches misreported as coming from a particular area may have been reported elsewhere).

A generalisation of the Pitcher *et al* (2002) methodology has been described by Pauly and Zeller (2015) as "catch reconstruction, undertaken using the following methodology:

1. Identification, sourcing and comparison of baseline reported catch times series, i.e., a) FAO (or other international reporting entities) reported landings data by FAO statistical areas, taxon and year; and b) national data series by area, taxon and year;
2. Identification of sectors (e.g., subsistence, recreational), time periods, species, gears etc., not covered by (1), i.e., missing data components. This is conducted via extensive literature searches and consultations with local experts;
3. Sourcing of available alternative information sources on missing data identified in (2), via extensive searches of the literature (peer-reviewed and grey, both online and in hard copies) and consultations with local experts. Information sources include social science studies (anthropology, economics, etc.), reports, colonial archives, data sets and expert knowledge;
4. Development of data 'anchor points' in time for each missing data component, and expansion of anchor point data to country-wide catch estimates;
5. Interpolation for time periods between data anchor points, either linearly or assumption-based for commercial fisheries, and generally via per capita (or per-fisher) catch rates for non-commercial sectors; and
6. Estimation of total catch times series, combining reported catches (1) and interpolated, country-wide expanded missing data series (5).
7. Quantifying the uncertainty associated with each reconstruction.

Table 5: Strengths and weaknesses of meta-analyses

Data type/source	Potential elements being estimated	Strengths	Weaknesses
Interpolations from multiple sources (anchor and influence points; catch reconstruction)	• Resolution depends on resolution of source data	• Use of many different sources allows cross-checks • Generates time series and allows reasonable extrapolations/interpolations to unobserved fleets • Different data sources can be given different quality markings and assigned confidence	• Difficult to consistently separate different types of IUU fishing • Establishing quality and overlap of individual contributing studies is difficult • As the scale increases, the potential for double counting increases. • Anchor points can be sparse, and the rationale for using management changes to infer interpolations, results in estimates with considerable uncertainty.

Source: Poseidon

An analysis of these meta-data type studies available shows the following:

- No single methodology appears to be used consistently for the estimation of IUU fishing. The closest that anything comes to being a consistent methodology is the anchor and influence method. No single methodology appears to be better than another, and of necessity studies in different regions need to take into account available data and information in that region.

- Although the best practice individual studies are able to estimate fairly precisely the amount of illegal or unreported activity on a specific species in a specific area (Aanes *et al*. (2011) for cod and haddock using data from fully inspected vessels, Payne *et al* (2005) using stock assessments; Agnew *et al* (2005) for CCAMLR using fisher behaviour and MCS modelling; Clark *et al* (2005 and 2009) using trade data for shark and salmon) this has only rarely contributed to global or regional estimates; furthermore they may or may not be able to identify specific IUU types.

- The most widely applied meta-data methodology (anchor and influence, and catch reconstruction) has sometimes been applied without full knowledge of the underlying data (often using secondary information, reports, anecdotal information rather than the more robust IUU estimation techniques above), without precise identification of IUU categories, and with a large number of assumptions to fill in the missing data holes. However, all use some robustly acquired data (the anchor) derived using the basic building blocks and in many cases the additional assumptions lead to fairly logical interpolations and extrapolations. Many of the better studies

along these lines seek to reduce uncertainty by triangulating amongst different sources and types of information (e.g. in Eritrea the changes in regime are clearly linked to changes in fishing behaviour by Tesfamichael and Pitcher, 2007). As noted above (Section 2.3) these methods have most widely been used in "catch reconstruction" for which IUU catches only form a part; but if estimation of total losses/extractions from marine ecosystems is the objective of a study, these provide probably the best estimate available, and have the advantage of being country-EEZ specific, therefore avoiding problems associated with double counting.

- The best regional studies appear to approach the problem using both quantitative and qualitative data and triangulating between different data sources. They utilise a wide range of building block data, with known or estimated statistical properties, distinguish and identify different IUU types, and triangulate results with other data such as trade data or expert judgement (Plagányi *et al*, 2011; Schwarz and Ishimura, 2014; Pramod *et al*, 2014; MRAG 2016). They also often undertake a risk assessment of the problem, and focus their analysis on the areas of highest risk (Funge-Smith *et al*, 2015). The results may not be simply quantified in tonnes of unreported IUU fish, but include estimates of economic losses and ecological impacts (MRAG, 2016). However, only rarely are ecological impacts (e.g. estimates of bycatch of birds or habitat damage) included.

- Much of the analysis above focusses on EEZs and areas under jurisdictional control (eg FFA waters, MRAG 2015; or south east Asian hot spots, Funge-Smith *et al*, 2015). The methods used by RFMOs to estimate IUU fishing follow no single methodology (see Table 6).

Table 6: Status of IUU estimation across selected RFMOs

Parameter	CCSBT	IATTC	ICCAT	IOTC	WCPFC	CCAMLR
Estimation technique	Market/ Trade based	Unknown but 100% coverage on purse seine vessels. Assumed no IUU	Case by case based on external knowledge approved by the Standing Committee on Research and Statistics	Case by case basis done internally by secretariat and approved by Scientific Committe e	Bottom up approach based on field and remote-sensing data	Bottom up based on MCS data, estimate of number of active IUU vessels, catch rates, and species composition

Source: Sharma (2016) and Poseidon data acquired from RFMOs. NAFO reported to the authors that they were not aware of any IUU in their region since 2006.

Other issues of quality

In considering the strengths and weaknesses of the studies reviewed (as documented in the fiches in Appendix 3), most studies specify well their objectives, scope and the main methodological approach being used.

However, in addition to inherent weaknesses in the different methodologies as discussed above and presented in

Table 4 and Table 5, many of the studies are poor in terms of:

- The large number of assumptions made, which lead to inevitable questions over the accuracy of the estimates produced. Some examples include: Ainsworth and Pitcher (2005), Agnew *et al* (2009), Aanes *et al* (2011), Funge-Smith *et al* (2015). Questions over accuracy are especially pronounced with studies that fail to provide ranges of estimates. Some of those that do provide such ranges, and implicitly or explicitly acknowledge uncertainty, include the recent FFA study (MRAG, 2016), and Agnew *et al* (2009).
- A lack of detailed source information being provided, supporting and allowing replicability and scrutiny of workings to derive estimates of IUU fishing. This is understandable for those studies reported in peer reviewed journal articles with length limitations, but is less justifiable in project reports. Notable exceptions of studies that provide good source information are the studies by Agnew *et al* (2009) which included all information in a 242 page report accompanying the main paper; and Pramod *et al* (2008).
- The failure to triangulate estimates. The best studies of IUU fishing have used a combination of methodologies, at different levels of resolution, to triangulate on quantities, impacts, and types of IUU fishing, but many do not. One particularly good example is Plagányi *et al* (2011) which triangulates stock assessment, police/surveillance and trade data to estimate illegal catches of abalone in South Africa.
- A failure by authors themselves to state, and be transparent about, the weaknesses and limitations of their work. Some studies that do state such limitations include: MRAG (2005), NASCO (2007), Funge-Smith *et al* (2015), MRAG (2016).
- Lack of transparency or robustness of statistical methods used to produce confidence intervals.

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

The context in which IUU fishing takes place has evolved considerably in recent years with improved governance at national, regional and international levels, and changing incentives and risks for vessels of engaging in IUU fishing. These changes are certain to have impacted on the amount of IUU fish catch globally, where IUU activities may take place, and the relative importance of different types of IUU fishing behaviour and which behaviours may now be most prominent. For example while the opportunities for vessels to engage in unregulated fishing are becoming ever smaller, misreporting may now be a major component of IUU fish catch.

Earlier studies to estimate IUU fishing at the *global level* served a useful advocacy purpose in providing ballpark estimates of the volume of IUU catch, but their usefulness can be questioned now that there is greater awareness about the problems of IUU fishing and the need to address it. The objective of estimating IUU fishing may now be more usefully focussed around generating estimates at a more *sub-national, national or regional levels* as the basis for practical targeting of fisheries management and MCS efforts to reduce IUU fishing, rather than just for the purposes of raising awareness of the IUU fishing problem.

The argument against devoting effort to generate an up-to-date global estimate is further bolstered by weaknesses that would be inherent in the methodology, which would be likely to reflect weaknesses in earlier studies. A new global estimate would almost certainly: lack accuracy and be highly uncertain; be unclear as to the IUU behaviors included due to the need to draw on other studies/analyses; fail to provide sufficient detail for all geographical areas, fleets, fish species, and types of fishing gear thereby having to reply on many assumptions in the process of scaling up the estimates from some individual studies to the global level. In addition, having a global figure as a benchmark to be monitored at periodic intervals (say every 5 years) may not be especially useful, as any future estimates would be likely to be based on evolving methodologies and would have to draw on information/data from a range of different studies each time, rendering direct comparison potentially rather meaningless. Furthermore confidence intervals of estimates in global studies are wide given the assumptions and uncertainty involved, so observing any *statistically significant change* between two time periods would be unlikely.

We therefore conclude that the global estimate of IUU catch suggested by the FAO-supported workshop in Rome in 2015 is not necessary or advisable from a technical point of view. We do however note that there may still be political impetus for such an estimate, and that in this case, FAO may be considered the most appropriate organisation to support the development of such an estimate given its global mandate for fisheries.

The technical guidelines for studies estimating levels of IUU fishing suggested by the Rome 2015 workshop, might nevertheless be useful in improving the quality of studies being completed at local, national or regional levels, given the variable quality in many of the studies that have been completed to date – such studies, in areas where governance and control

resources are weak, and/or where key resources are subject to overfishing, would certainly be useful.

Given the lack of consistency in studies as to aspects of I, U, and U fishing being estimated, and common misunderstanding about what IUU activities are included in the definitions of IUU fishing in the IPOA-IUU, if technical guidelines are to be prepared to inform the completion of studies estimating levels of IUU fishing activity, it would be useful for such guidelines to revisit the definitions of IUU as articulated in the IPOA-IUU, and to provide further elaboration, and potentially sub-division of these categories. However, given the emerging range of definitions of IUU as highlighted in Section 1.4, it may still be necessary to leave future studies some room to define what they mean by IUU fishing within the context of the analysis they might wish to conduct.

In addition, technical guidelines on estimating IUU fishing should make it clear that studies to estimate IUU fishing within the content of the IPOA-IUU and efforts to tackle the 'crime' of IUU fishing, should not include studies that focus on estimating 'total removals' i.e. which may include recreational and subsistence catches even when such catches are not illegal, unreported or unregulated in terms of the IPOA-IUU definitions. Furthermore, such guidelines could usefully note that the economic and social impacts of IUU fishing activities may not result from *non*-reporting of catch data but rather from misreporting. This means that the *volumes* of IUU catch which are the focus of catch accounting methodologies, may need to be accompanied by sufficient focus on the *value* to fishers of IUU activity and the associated costs to society. A stronger focus on estimating *values* of IUU catch for different types of IUU behavior and for different fleet types and fishing gear, rather than just volumes as tends to be the case in many studies, would generate information about the importance and benefits of devoting sufficient management and MCS resources at reducing IUU fishing activity, while also serving to inform the priority focus areas for such resources so as to maximise efficiency and cost effectiveness.

Considering that the objective of actively contributing towards efforts to combat IUU fishing and reduce levels of IUU catch may now be of greater priority than just raising awareness of the problem, also of great benefit would be the development of *technical guidelines on risk-based assessments of IUU fishing*. A number of frameworks for IUU risk assessments are being used by RFMOs and national administrations. But as the 5th GFETW in Auckland observed in March 2016, there is currently no guidance on how to complete such assessments, and many developing and developed countries alike would benefit from technical guidance. The completion of IUU risk assessments could also, but need not necessarily, result in and be the basis for estimates of IUU catches. The first step in developing such technical guidelines would be the preparation of an inventory and review of all existing risk assessment frameworks in use. FAO could take the lead in developing such guidelines as FAO is the appropriate organisation to do so with its global fisheries mandate.

Indicators of IUU fishing to monitor progress in combatting IUU fishing internationally are critically important in terms of both benchmarking and monitoring progress over time in combatting IUU fishing activity. However for the reasons stated above we conclude that IUU activities indicators should not include a global estimate of IUU catch. Indicators could however focus on other aspects such as numbers of vessels on IUU fishing vessel lists, number

of countries issued with yellow and red cards under the EU IUU regulation, the outputs of IUU risk-based assessments, and perhaps some specific regional or local estimates of IUU activities in high risk areas based on repeatable and robust methodologies. Technical work and stakeholder consultation would need to be undertaken to identify and agree on the appropriate indicators, and FAO would be the logical organisation to lead such work. It would also need to be agreed where and how such indicators should be published; possibilities might include a 'live' dashboard of indicators being hosted by an organisation such as FAO and regularly updated, or alternatively more static indicators published periodically, for example in FAO's bi-annual flagship publication, State of the World Fisheries and Aquaculture (SOFIA), as recommended by the Rome 2015 workshop.

3.2 RECOMMENDATIONS

Given the findings as presented in Section 2 of this report, and the conclusions as presented in Section 3.1 above, this study of studies makes a number of recommendations to COFI for consideration at its 32nd session in July 2016. These recommendations at that COFI should advise and consider whether:

(i) an updated global estimate of IUU catch is desirable and if so what would be its objective and what role FAO should have in supporting/developing such an estimate.

(ii) FAO should lead a process to develop technical guidelines to improve the quality of studies completed at local, national and regional levels to estimate IUU catch (even if a global estimate of IUU catch is not considered important), and whether such guidelines should revisit the IPOA-IUU definitions, not necessarily departing from them but identifying separate categories of IUU that should be considered in risk assessments and monitoring studies that are more attuned to current experience and practices.

(iii) FAO should support the development of technical guidelines on conducting IUU risk-based assessments.

(iv) reporting globally on indicators of IUU fishing would be beneficial, and if so what the process should be for proposing, agreeing and reporting on such indicators, and what role FAO should play in such a process.

Appendix 1: List of studies reviewed for which a fiche has been prepared

Aanes, S., Nedreaas, K., Ulvatn, S. (2011) Estimation of total retained catch based on frequency of fishing trips, inspections at sea, transhipment, and VMS data. *ICES Journal of Marine Science: Journal du Conseil* 68, 1598-1605.

Agnew, D.J. (2000) The illegal and unregulated fishery for toothfish in the Southern Ocean, and the CCAMLR catch documentation scheme. *Marine Policy* 24, 361-374.

Agnew, D.J., Kirkwood, G.P. (2005) A statistical method for analysing the extent of IUU fishing in CCAMLR waters: application to CCAMLR Subarea 48.3. *CCAMLR Science* 12, 119-141.

Agnew, D.J., Pearce, J., Pramod, G*., et al.* (2009) Estimating the Worldwide Extent of Illegal Fishing. *PLoS ONE* 4, e4570.

Ainsworth, C.H., Pitcher, T.J. (2005) Estimating illegal, unreported and unregulated catch in British Columbia's marine fisheries. *Fisheries Research* 75, 40-55.

Al-Abdulrazzak, D., Zeller, D., Belhabib, D., Tesfamichael, D., Pauly, D. (2015) Total marine fisheries catches in the Persian/Arabian Gulf from 1950 to 2010. *Regional Studies in Marine Science* 2, 28-34.

Ball, I. (2005) An alternative method for estimating the level of IUU fishing using simulated scaling methods on detected effort. *CCAMLR Science* 12, 143–161. (*see fiche for Agnew and Kirkwood 2005*).

Belhabib, D., Koutob, V., Sall, A., Lam, V.W.Y., Pauly, D. (2014) Fisheries catch misreporting and its implications: The case of Senegal. *Fisheries Research* 151, 1-11.

Bremner, G., Johnstone, P., Bateson, T., Clarke, P. (2009) Unreported bycatch in the New Zealand West Coast South Island hoki fishery. *Marine Policy* 33, 504-512.

Cisneros-Montemayor, A.M., Cisneros-Mata, M.A., Harper, S., Pauly, D. (2013) Extent and implications of IUU catch in Mexico's marine fisheries. *Marine Policy* 39, 283-288.

Clarke, S.C., McAllister, M.K., Kirkpatrick, R.C. (2009) Estimating legal and illegal catches of Russian sockeye salmon from trade and market data. *ICES Journal of Marine Science: Journal du Conseil* 66, 532-545.

Clarke, S.C., McAllister, M.K., Milner-Gulland, E.J*., et al.* (2006) Global estimates of shark catches using trade records from commercial markets. *Ecology Letters* 9, 1115-1126.

Coll, M., Carreras, M., Cornax, M.J*., et al.* (2014) Closer to reality: Reconstructing total removals in mixed fisheries from Southern Europe. *Fisheries Research* 154, 179-194.

Coalition of Legal Toothfish Operators (2015). Estimates of IUU toothfish catches in the 2014/2015 season. CCAMR-XXXIV/BG/12

Free, C.M., Jensen, O.P., Mendsaikhan, B. (2015) A Mixed-Method Approach for Quantifying Illegal Fishing and Its Impact on an Endangered Fish Species. *PLoS ONE* 10, e0143960.

Funge-Smith, S., Lee, R., and Leete, M., (2015). Asia-Pacific Fishery Commission. Regional review of Illegal, Unreported, and Unregulated (IUU) fishing by foreign vessels. RAP Publication 2015/09.

Glazer, S., Roberts, P., Mazurek, R., Hurlburt, K., and Kane-Hartnett, L., 2015. Securing Somali Fisheries. Secure Fisheries report.

Green, T.J., and McKinlay, J.P., 2009. Compliance program evaluation and optimisation in commercial and recreational Western Australian fisheries. Fisheries Research and Development Corporation Final Report, Project 2001/069:, 77 pp.

Hentati-Sundberg, J., Hjelm, J., Österblom, H. (2014) Does fisheries management incentivize non-compliance? Estimated misreporting in the Swedish Baltic Sea pelagic fishery based on commercial fishing effort. *ICES Journal of Marine Science: Journal du Conseil* 71, 1846-1853.

ICES (2014) Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 30 April–7 May 2014. ICES CM 2014/ACOM:13, Pages 795-797 and Figure 14.9a.

Kleiven, A.R., Olsen, E.M., Vølstad, J.H. (2012) Total Catch of a Red-Listed Marine Species Is an Order of Magnitude Higher than Official Data. *PLoS ONE* 7, e31216.

Leitão, F., Baptista, V., Zeller, D., Erzini, K. (2014) Reconstructed catches and trends for mainland Portugal fisheries between 1938 and 2009: implications for sustainability, domestic fish supply and imports. *Fisheries Research* 155, 33-50.

Lescrauwaet, A.-K., Torreele, E., Vincx, M., Polet, H., Mees, J. (2013) Invisible catch: A century of bycatch and unreported removals in sea fisheries, Belgium 1929–2010. *Fisheries Research* 147, 161-174.

MRAG (2005) Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries.

MRAG. (2015). Review of impacts of Illegal, Unreported, and Unregulated Fishing on Developing countries in Asia. FAO / BOBLME secretariat report.

MRAG (2016) Towards the quantification of Illegal, Unreported And Unregulated (IUU) Fishing in the Pacific Islands Region. A report prepared for the Pacific Island Forum Fisheries Agency (FFA).

NASCO (2007) Presentations Made at the 2007 Special Session on Unreported Catches. 49 p. Nurhakim S, Nikijuluw VPH, Badrudin M, Pitcher TJ, Wagey GA (2008) A Study Of Illegal, Unreported and Unregulated (IUU) Fishing In The Arafura Sea, Indonesia. Rome: FAO. pp 41.

OECD (2004) Compiling the evidence *In*: Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing. OECD Publishing. 404 p (relevant section: 107 p)

Pauly, D., Zeller, D. editors. (2015). Catch Reconstruction: concepts, methods and data sources. Online Publication. Sea Around Us (www.seaaroundus.org). University of British Columbia. In Pauly, D., and Zeller D., editors. 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining.

Pauly, D., Belhabib, D., Blomeyer, R.*, et al.* (2014) China's distant-water fisheries in the 21st century. *Fish and Fisheries* 15, 474-488.

Payne, A.G., Agnew, D.J., Brandão, A. (2005) Preliminary assessment of the Falklands Patagonian toothfish (Dissostichus eleginoides) population: Use of recruitment indices and the estimation of unreported catches. *Fisheries Research* 76, 344-358.

Pham, C.K., Canha, A., Diogo, H., Pereira, J.G., Prieto, R., Morato, T. (2013) Total marine fishery catch for the Azores (1950–2010). *ICES Journal of Marine Science: Journal du Conseil* 70, 564-577.

Piroddi, C., Gristina, M., Zylich, K.*, et al.* (2015) Reconstruction of Italy's marine fisheries removals and fishing capacity, 1950–2010. *Fisheries Research* 172, 137-147.

Pitcher, T.J., Watson, R., Forrest, R., Valtýsson, H.Þ., Guénette, S. (2002) Estimating illegal and unreported catches from marine ecosystems: a basis for change. *Fish and Fisheries* 3, 317-339.

Plagányi, É., Butterworth, D., Burgener, M. (2011) Illegal and unreported fishing on abalone—Quantifying the extent using a fully integrated assessment model. *Fisheries Research* 107, 221-232.

Polacheck, T. (2012) Assessment of IUU fishing for Southern Bluefin Tuna. *Marine Policy* 36, 1150-1165.

Pramod, G., Nakamura, K., Pitcher, T.J., Delagran, L. (2014) Estimates of illegal and unreported fish in seafood imports to the USA. *Marine Policy* 48, 102-113.

Restrepo V. R. (2004) Estimation of unreported catches by ICCAT. ICCAT Secretariat. *In*: OECD (2004) *Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing*. Chapter 9 pp. 155 - 158. OECD Publishing.

Sabourenkov, E.N, Miller, D.G.M (2004) The Management of transboundary stocks of toothfish, Dissostichus spp, under the convention for the conservation of Antarctic marine living resources. *In* AIL Payne, CM O'Brien, SI Rogers (eds) Management of shared fish stocks, Blackwell, Oxford, pp 68-94. (see fiche for Agnew 2000).

Swartz, W., Ishimura, G. (2014) Baseline assessment of total fisheries-related biomass removal from Japan's Exclusive Economic Zones: 1950-2010. *Fisheries Science* 80, 643-651.

Tesfamichael, D., Pitcher, T.J. (2007) Estimating the unreported catch of Eritrean Red Sea fisheries. *African Journal of Marine Science* 29, 55-63.

Varkey, D.A., Ainsworth, C.H., Pitcher, T.J., Goram, Y., Sumaila, R. (2010) Illegal, unreported and unregulated fisheries catch in Raja Ampat Regency, Eastern Indonesia. *Marine Policy* 34, 228-236.

Wagey, G., Nurhakim, S., Nikijuluw, K., Badrudin, and Pitcher, T. (2009). A study of IUU fishing in the Arufa Sea, Indonesia.

Williamson DH, Ceccarelli DM, Evans RD, Hill JK, Russ GR. (2014). Derelict fishing line provides a useful proxy for estimating levels of non-compliance with no-take marine reserves. PLoS One. 2014; 9(12): e114395.

Willock A. (2004) Using Trade and market information to assess IUU fishing activities. TRAFFIC International. *In*: OECD (2004) *Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing*. Chapter 5 pp. 67 - 77. OECD Publishing.

Worm, B., Davis, B., Kettemer, L*., et al.* (2013) Global catches, exploitation rates, and rebuilding options for sharks. *Marine Policy* 40, 194-204.

Zeller, D., Rossing, P., Harper, S., Persson, L., Booth, S., Pauly, D. (2011) The Baltic Sea: Estimates of total fisheries removals 1950–2007. *Fisheries Research* 108, 356-363.

Appendix 2: Other references related to IUU fishing but for which fiches have not been prepared

Anganuzzi A., (2004) Gathering data on unreported activities in Indian Ocean Tuna fisheries. IOTC Secretariat. *In*: OECD (2004) *Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing*. Chapter 8 pp. 147 - 154. OECD Publishing.
Reports on legal/illegal vessels, not on estimates of IUU catch from those vessels. So more a focus on compliance.

Blank, S.G., and Gavin, M.C. (2009) The randomized response technique as a tool for estimating non-compliance rates in fisheries: a case study of illegal red abalone (Haliotis rufescens) fishing in Northern California. Environmental Conservation 36, 112-119.
Paper focuses on compliance rates (using randomized surveys) with licences, size, and daily limits. Compliance with bag limits not converted in estimates of IUU catch volumes.

Borit, M., Olsen, P. (2012) Evaluation framework for regulatory requirements related to data recording and traceability designed to prevent illegal, unreported and unregulated fishing. *Marine Policy* 36, 96-102.
Discusses traceability options to detect IUU fish in general.

Bray, K. (2000) - A Global Review of Illegal, Unreported and Unregulated (IUU) Fishing. Document AUS:IUU/2000/6. 53 p.
The report is outside the timeframe/scope of our review, and presents the views of RFMOs on IUU fishing with qualitative and quantitative records (e.g. sights of IUU fishing activities), and ways to combat it (e.g. signature of international agreements, use of VMS, information exchange and cooperation between RFMOs and countries and port State controls). It does provide quantitative estimates of IUU fishing in specific areas but sporadically only: for instance, CCAMLR estimated the extent of IUU toothfish fishing from 1997 to 1999 of the order of 90,000 tonnes in the area managed by the RFMO, more than twice the level of catches taken in CCAMLR-regulated fisheries.

Campbell, M.L., Gallagher, C. (2007) Assessing the relative effects of fishing on the New Zealand marine environment through risk analysis. *ICES Journal of Marine Science: Journal du Conseil* 64, 256-270.
No estimates of IUU fishing provided. However, presents an interesting methodology for risk assessment of ecological impacts of fishing.

Davies, R.W.D., Cripps, S.J., Nickson, A., Porter, G. (2009) Defining and estimating global marine fisheries bycatch. *Marine Policy* 33, 661-672.
Information on global estimates of bycatches, not IUU fishing.

Gillett, R., 2011. Bycatch in small-scale tuna fisheries, a global study. FAO Technical Paper 560.
The study focuses on estimating quantitatively the global volume of by-catch in small-scale tuna fishing, which are 'non-tuna species' and 'non-target species' or, in some countries, undersized fish and damaged fish (gear: rods, reels, trolls, longlines, handlines).

Greenpeace, 2015. Licensed to Loot. A Greenpeace India investigation on the letter of permit scheme.
The report investigates the impacts of abuses of the Indian letter of permit scheme. Two estimates of IUU fishing are quoted in the report and coming from other quantitative studies on IUU fishing: David Agnew et al.'s 2009 global estimate of IUU fishing and the loss of legal trade of products from IUU fishing in India (MRAG and University of British Columbia, 2008).

Gianni W. and Simpson W. (2004) Flags of convenience, transshipment, re-supply and at-sea infrastructure in relation to IUU fishing. International Oceans Network for WWF In: OECD (2004) Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing. Chapter 6 pp. 79 - 104. OECD Publishing.
The paper does not focus on presenting a method to quantify IUU fishing activities but on a) trends in the number of fishing vessels with flags of convenience in the early 2000s, b) at-sea and re-supply transshipment and recommendations to manage these activities and c) recommendations to implement the 2001 UN FAO international plan of action on IUU fishing.

Green, T.J., and McKinlay, J.P. (2009) Compliance program evaluation and optimisation in commercial and recreational Western Australian fisheries. Fisheries Research and Development Corporation Final Report, Project 2001/069:, 77 pp.
Not a focus on IUU but rather on the difficulties around measuring noncompliance more generally.

Henderson. M. and Fabrizio, M. (2013) Detecting Noncompliance in the Summer Flounder Recreational Fishery Using a Mark Recapture Growth Model, North American Journal of Fisheries Management, 33:5, 1039-1048.
Used tagged fish and a mark-recapture growth model to estimate non-compliance in % terms with minimum length regulations, but did not estimate volumes of IUU caught fish.

Hoydal K. (2004) IUU fishing in the NEAFC area: how big is the problem and what have we done? NEAFC. In: OECD (2004) Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing. Chapter 10 pp. 159 - 165. OECD Publishing.
The paper only provides a qualitative situation of IUU fishing activities (illegal fishing) and present cases of vessels having been refused by Port States to land illegal catch of species harvested in the NEAFC area.

King, D.M., and Sutinen, J.G. (2010) Rational noncompliance and the liquidation of Northeast groundfish resources. Marine Policy 34, 7-21.
A study of compliance levels and incentives to infringe based on resulting illegal benefits, sanctions and likelihood of detection. No estimates of IUU per se just some estimates of % of catch taken illegally.

Kindt-Larsen, L., Kirkegaard, E., and Dalskov, J. (2011) Fully documented fishery: a tool to support a catch quota management system. ICES J. Mar. Sci. 68(8), 1606-1610.
Study comparing skipper estimates of cod discards with those form video footage. No estimates of volumes of IUU catch per se, just compliance with the requirement to record all discards.

Marteache, N., Viollaz, J., and Petrosian, G.A. (2015). Factors influencing the choice of safe haven for offloading illegally caught fish: a comparative analysis of developed and developing countries. In Crime Science (2015) 4:32
Study does not provide a method of estimating IUU catch volumes, only idenfication of factors influencing where IUU catch are most likely to be landed.

McCluskey, S.M., Lewison, R.L. (2008) Quantifying fishing effort: a synthesis of current methods and their applications. *Fish and Fisheries* 9, 188-200.
This is a review paper, providing some useful suggestions (including the use of models that include distance from port as a parameter within probabilistic encounter models) but is not an IUU study and therefore not relevant for the review.

Miller, D.D., Sumaila, U.R. (2014) Flag use behavior and IUU activity within the international fishing fleet: Refining definitions and identifying areas of concern. *Marine Policy* 44, 204-211.
Report attempts to classify flags into different categories (flag of non-compliance, flag of integrity, flag of partial legislation, flag of no legislation) based on different criteria. There is no quantification of the effects of flags on amounts of IUU fishing.

Miller D.G.M. (2004) Patagonian Toothfish – the storm gathers. CCAMLR. In: OECD (2004) Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing. Chapter 7 pp. 105 - 146. OECD Publishing.
Contains Some useful information on the method applied by the CCAMLR but a repetition of 'Sabourenkov et Miller (2004)' (for which a fiche has been created).

MRAG (2005b) IUU fishing on the high seas: Impacts on Ecosystems and Future Science Needs. 71 p. A report prepared by MRAG for the UK's Department for International Development (DFID), with support from the Norwegian Agency for Development Cooperation (NORAD).
A study assessing the impacts of IUU fishing based on findings of MRAG 2005a (see fiche).

MRAG (2008) Study and analysis of the status of IUU fishing in the SADC region and an estimate of the economic, social and biological impacts. Volume 2-Main Report. Marine Resource Assessment Group. 74 p.
The study focuses on factors and impacts of IUU fishing in the SADC region and includes a couple of case studies of IUU fishing in the region only. It provides a few trend analyses on estimated IUU fishing in the Indian Ocean, from large deep freezer longliners, and in the CCAMLR region, for Patagonian toothfish. These estimates are based on other articles or reports.

Mullowney, D.R., and Dawe, E.G. (2009) Development of performance indices for the Newfoundland and Labrador snow crab (Chionoecetes opilio) fishery using data from a vessel monitoring system. Fisheries Research 100, 248-254.
Compliance study comparing CPUE based on VMS data and logbooks.

NASCO (2015) Report on Progress in Implementing the Measures contained in the 'Action Plan for taking forward the recommendations of the External Performance Review and the review of the 'Next Steps' for NASCO' 16 p.

Estimates of recent unreported catch to NASCO are contained in the document CNL(15)13 (http://www.nasco.int/pdf/2015%20papers/CNL_15_13.pdf). The section 2.1 'IUU fishing by non-NASCO parties' presents actions undertaken by NASCO and NASCO parties to detect and fight IUU fishing by collected and exchanged information obtained throughout airborne and shipborne surveillance programmes carried out by countries and regional fisheries organisations (e.g. NAFO, NEAFC, ICCAT). The section 2.2. 'IUU fishing by NASCO parties' reports measures to reduce the level of unreported catches.

ORCA-EU (2007) A report on IUU fishing of Baltic Sea. Report published by the Fisheries Secretariat (FISH)
The study itself does not estimate IUU fishing in the Baltic Sea cod fisheries. It analyses attempted estimates of unreported catches provided by the International Council for the Exploration of the Sea (ICES) within its fisheries assessment advice to the European Commission.

Pascoe, S., Okey, T.A., Griffiths, S. (2008) Economic and ecosystem impacts of illegal, unregulated and unreported (IUU) fishing in Northern Australia. Australian Journal of Agricultural and Resource Economics 52, 433-452.
Not an estimate of IUU; it is an attempt to look at what might be the ecosystem impacts, and lost net economic value to the legal fleet, of the IUU fishing if, as assumed and reported, it has increased from 10% to 100% of the legal catch and effort has increased 17 fold.

Petrossian, G.A., and Clarke, R. (2013). Explaining and controlling illegal commercial fishing. British Journal of Criminology. An application of the CRAVED theft model.
Doesn't estimate volumes of IUU catch, rather takes species identified by other sources e.g. consumer guides and other published studies as IUU, and compares their characteristics to those of legally caught species to determine what are the key characteristics that increase risks of IUU catch.

Petrossian, G.A., Marteache, N., Viollaz, J. (2015) Where do "Undocumented" Fish Land? An Empirical Assessment of Port Characteristics for IUU Fishing. European Journal on Criminal Policy and Research 21, 337-351.
Not a study estimating volumes of IUU just where risks of IUU fish landings are highest.

Petrossian, G.A. (2015) Preventing illegal, unreported and unregulated (IUU) fishing: A situational approach. *Biological Conservation* 189, 39-48.
Identifies situations and risks facilitating IUU fishing, not volumes of IUU catch.

Petrossian, G., Weis, J.S., Pires, S.F. (2015) Factors affecting crab and lobster species subject to IUU fishing. Ocean and Coastal Management 106, 29-34.
Doesn't estimate volumes of IUU catch, rather takes species identified by UBC as IUU and compares their characteristics to those of legally caught species to determine what are the key characteristics that increase risks of IUU catch.

Sharma, R., 2016. Illegal, Unregulated and Unreported Catches in tuna Regional Fisheries Management Organizations and quantification of their effects on Assessments.

Discusses ways in which tuna RFMOs incorporate IUU estimates into stock assessment models. Not a paper to estimate IUU fishing.

Smartfish (2012) IUU Fishing on Lake Tanganyika Report # SF/2012/15
In 2011, the Lake Tanganyika Authority (LAT) undertook a lake-wide frame survey that attempted to estimate some of the IUU fishing activities (estimating the use of illegal gears) on the Lake. Although presenting quantitative data, the report does not provide the detailed method applied by the Survey to estimate the number of illegal gears, and does not estimate illegal catches.

Smartfish (2012) Assessment of IUU Activities on Lake Victoria Report # SF/2011/12
The study does not estimate a volume of illegal fishing on Lake Victoria per se but assesses the state of IUU fishing activities on the Lake focusing on undersized (illegal) Nile Perch fishing from 2000 to 2008.

Tsamenyi, M., Kuemlangan, B., Camillieri, M. (2015). Defining Illegal, Unreported and Unregulated (IUU) Fishing. FAO Expert Workshop to estimate the magnitude of Illegal, Unreported and Unregulated fishing globally, Rome 2-4 February 2015.
This paper analyses the definitions of IUU fishing set out by the FAO-IPOA outlining possible overlaps and proposing an operational categorization of I, U and U

Thomas, A., Gavin, M., Milfont, T. (2015). Estimating non-compliance among recreational fishers: insights into factors affecting the usefulness of the Randomised Response and Item Count Techniques. Biological Conservation (in press).
Paper focuses on compliance rates with marine reserves, size limit, and daily limits. Compliance not converted in estimates of IUU catch volumes.

WWF, 2015. Illegal fishing. Which species are at highest risk from illegal and unreported fishing.
Uses Agnew et al (2009) global study on IUU levels, Pramod et al (2015) and FAO stock assessment data to determine species and stocks risk of IUU fishing. Not a study itself to estimate levels of IUU fishing, just to identify species/stocks/areas subject to highest risk.

Ye, Y., Valbo-Jørgensen, J. (2012) Effects of IUU fishing and stock enhancement on and restoration strategies for the stellate sturgeon fishery in the Caspian Sea. *Fisheries Research* 131–133, 21-29.
This paper does not estimate IUU, and only uses earlier estimates which are outside the timeframe of our study.

Zeller, D., Booth, S., Davis, G., Pauly, D. (2007) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. Fish. Bull. 105, p. 266-277. http://fishbull.noaa.gov/1052/zeller.pdf
Pre 2009 and so outside scope of this study of IUU studies.

Appendix 3: Summary fiches for studies listed in Appendix 1

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Aanes et al. (2011)</td><td>2011</td><td>Institute of Marine Research, Norway</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of total retained catches of certain species.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Barents Sea</td><td>Large scale trawlers targeting cod and haddock</td><td>2002-2009</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Underreporting of landing data (including transhipments at sea)</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Use of data on fully inspected vessels to determine anchor points (average weight of fisheries products onboard by trip as function of capacity expressed in GRT) and extrapolation to total fleet using presence data from VMS and AIS.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Records of inspections (verification of landing data)
• Register of licensed vessels
• VMS data
• AIS data</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Raising factors to be applied to official landing statistics over the period for each of the two species considered.
Raising factors produced have been used by ICES to rectify official landing statistics in the frame of stock assessment.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Extensive use of MCS data available from Norwegian control authorities
• Very limited use of expert judgements on extent of IUU (factual basis for estimate produced)</td><td>• Assumptions on presentations of catches onboard (whether whole, H&G or fillets) having a potentially large impact on estimates</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Limited to context of large scale commercial fisheries (i.e. with few or no small-scale fishing activities) with reasonable levels of inspection activities.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Agnew (2000); And Sabourenkov and Miller (2004); and CCAMLR (2015)	Various	CCAMLR
Study Objective		
Estimation of unregulated and illegal catches of toothfish.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Antarctic	Commercial Longlining and gillnetting	1995-2015
Types of IUU activities considered by the study		
Commercial catches, bycatch and incidental mortality by non-parties (unregulated) and by illegal activities of vessels flagged to non-parties but under ownership of entities residing in parties; thus mostly FAO definition 3.3.1. [note: in respect of illegal activity of nationals of Parties, Spain recently concluded operation Sparrow against such nationals, levying €17.8m in fines; http://www.colto.org/2015/12/17/operation-sparrow-investigation-complete-e17-84-million-in-fines/)		
Main methodology followed		
IUU quantity = estimated number of vessels active x trip length x catch rates by fishing area. Occasionally triangulation with trade data allows cross checking. (the CCAMLR Compliance Committee has also previously used catch rate data to identify suspected illegal fishing by Member vessels).		
Data sources used		
• n. vessels estimated from reports of landings (named vessels identified), sightings by fishing vessels and patrol vessels; in some areas estimates of unlicensed vessels are available from SAR imagery matched with VMS data, but this is not available in high latitudes • fishing area estimated from sightings areas • trip length calculated from likely hold size, catch rates and seasonal accessibility of ice-free fishing areas • catch rates estimated from observer data from legal vessels, including data from legal vessels prior to the introduction of mitigation methods • catch document scheme total legal traded catch compared to legal catch reported by observers		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
• Estimates of catches of target species, bycatch and incidental mortality by statistical area, on an annual basis • Medium quality, dependent upon accuracy of source information		
Strengths	**Weaknesses**	
• Based on multiple data sources allows triangulation in estimate of number of active vessels • Observer data provides highly accurate data for comparison with suspect vessels and estimation of likely catch rates on IUU vessels, and also estimates of bycatch including birds, mammals	• In the late 2000s the IUU vessels introduced set gillnets for which CCAMLR had no plausible estimates of catch rates, and the calculations were stopped • New methods are being developed based on hold capacity and observed	

• Additional triangulation occasionally provided through trade data analysis • Estimates were better when IUU fishing was high, and are now more uncertain, which is appropriate given the seriousness of the problem • Industry and NGOs play major parts in providing data, increasing acceptance of estimates • Accuracy of estimates increased in 2014 with identification of specific vessels, capture of Thunderer, identification of catch rates from recovered nets (see CCAMLR, COLTO, 2015)	landings, but these cannot estimate bycatch, or ghost fishing • Imperfect knowledge of number of vessels (sightings surveys are partial in the Antarctic) and areas fishing means high confidence intervals in the estimates • Areas that are closed to fishing degrade the estimates in these areas
Transferability of method to other situations? Ability to contribute to a global estimate?	
• Versatile methodology based on multiple data sources and estimation methods, allowing triangulation of outcomes • High cost, requiring observers on legal vessels and significant investigatory work. • High ability to contribute to global estimate of any definition of IUU	

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Agnew and Kirkwood (2005); and
Ball (2005)</td><td>2005</td><td>Imperial College; Australian Antarctic Division</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimating illegal catches of toothfish in South Georgia waters.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>South Atlantic, South Georgia</td><td>Commercial Longlining</td><td>1998-2004</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Illegal (pirate) fishing, including non-reporting, fishing without licence, fishing without applying regulations.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Uses compliance theory. Estimation of likely IUU vessel activity (days fishing) given known patrol vessel activity, IUU vessel/gear sightings, and modelled encounter probability, combined with known legal vessel catches. A modification by Ball (2005) proposed a solution to the zero-observation problem but could not be parameterised.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Patrol vessel tracks
• Sightings data
• Observer data on legal vessels
• Estimated trip lengths of IUU vessels based on hold capacity and behaviour of legal vessels.</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">• Estimates of catches of target species, bycatch and incidental mortality, with confidence intervals
• Ability to distinguish different types of IUU
• High quality</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Statistically robust, utilising existing accurate patrol vessel data and observer data</td><td>• Model was designed specifically for the case, in which the topography allowed limited avoidance behaviour
• Model less accurate where zero sightings are made, a problem solved by the Ball modification
• The prevention/detection problem affects observations of IUU vessels (high real detection leads to evasion and lower detection probability)</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">• Data and modelling intensive. However, modelling approach to estimating IUU activity from sightings data could be adapted for other situations
• Could contribute to global estimate of any part of IUU definition, but has not been used by CCAMLR or other organisations since</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Agnew et al. (2009)</td><td>2009</td><td>Funding: UK Dept. for International Development</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Global estimate of IUU fishing</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Global</td><td>Commercial</td><td>1980-2003</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">All types, including unreported (legal) catches. Separation was not possible.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Anchor points and influence table approach (Pitcher et al 2002). Exhaustive literature searches on explicit quantitative estimates of IUU plus anecdotal reports in 54 countries to generate fixed points and indications of trends based on changes to regulatory environment or other factor.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Literature searches, incorporating many different types of quantitative and qualitative data on IUU, weighted by data quality.</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">Global estimates by region were produced to avoid double counting as far as possible, and by species group where possible. Trends over time were produced. Although data were produced by country these were not in the final publication as they were likely to include double counting.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Global coverage
• Quality of data acknowledged and factored into the confidence intervals of the estimates
• Many fixes possible for anchor points
• Probably reasonably accurate at a global scale
• All sources comprehensively published</td><td>• Use of influence assumptions degrades accuracy with the Pitcher method
• Data very scarce for some countries and regions leads to imbalance in data accuracy across the world, probably in areas where IUU is highest
• Not accurate at fishery level or able to easily separate different types of IUU</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">Could be repeated by extending the data set beyond 2013.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Ainsworth and Pitcher (2005)</td><td>2005</td><td>UBC, Vancouver, BC, Canada</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of total removals (illegal and unreported catches, discards) of certain species.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Fishing area off British Columbia</td><td>Commercial and recreational fisheries targeting groundfish and salmon</td><td>1950-2003</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Illegal catches defined as catches concealed or misreported (including discards) and unreported catches.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">IUU influence factors and anchor points used to apply correction factors to official catch data.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Official catch data
• Regulatory changes (determine incentives for non-compliance)
• Records of infringements (illegal catches)
• Discard data from onboard sampling (discard data)
• Surveys recreational fishermen (unreported recreational catch data)</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Comparisons against official reported data separating i) groundfish (all species aggregated) and salmon and ii) source of misreporting (discards, illegal and unreported)</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Comprehensive approach taking into account recreational fishing (significant for salmon for the case study)
• Metiers differentiation in estimates (i.e. trawl, seine, hook and line)
• Take into account incentives for IUU activities to quantify extent of IUU fishing on the basis of the evolution of the management framework (e.g. introduction of closed areas, quotas)</td><td>• Does not address potential underreporting of landings by commercial vessels
• Paucity of robust anchor points due to inadequate records of inspections and infringements, and low observer coverage
• Extensive use of assumption to quantify extent of IUU fishing
• No or unclear considerations on total inputs (number of active fishing units or total fishing effort)</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Yes, as a first approach - although underreporting by commercial vessels should be considered in the scope.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Al-Abdulrazzak et al. (2015)</td><td>2015</td><td>UBC, Vancouver, BC, Canada</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of total removals (illegal and unreported catches, discards) of fisheries products.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Persian Gulf</td><td>Commercial (including discards), recreational and subsistence fisheries</td><td>1950-2010</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">No definition provided. Illegal catches included as “other unreported” catches from commercial vessels.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Use of anchor points to determine likely extent of catches (incl. discards) obtained by commercial / recreational and subsistence fisheries.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Officially reported landings
• Discarding rates available from literature for different types of commercial fishing activities (i.e. shrimp fisheries, finfish fisheries)
• Assumed numbers of recreational fishermen as a proportion of total population with estimates of effort and catch per day
• Estimates of consumption of fisheries products by Coastal population (subsistence fisheries)
• Estimates amounts of illegal catches by commercial vessels</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Total removals of fisheries species by taxa, by type of activity (commercial fishing, subsistence, recreational) and by country over the 1920-2010 period. No published estimates of illegal catches.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Comprehensive approach
• Attempt to provide estimates of total removal in a data-poor environment</td><td>• Transparency of estimates
• Large recourse to expert judgment for quantifying extent of unknown catches
• Paucity of robust anchor points
• Assumed stability of uncertainty over time
• No considerations on the reliability of reported commercial landings which are used to derive some estimates (amounted discarded, illegal catches)
• No separate quantification of illegal catches
• No references to potentially available data from inspections / detected infringements</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Yes, as a first approach</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Belhabib et al. (2014)</td><td>2014</td><td>UBC, Vancouver, BC, Canada</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of total removals (illegal and unreported catches, discards) of fisheries products within Senegal EEZ and by Senegal fleets outside National EEZ.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Fisheries under the competency of Senegal</td><td>Domestic and foreign commercial fishing (incl. discards), subsistence and recreational fishing</td><td>1950-2010</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">IUU activities considered include unreported catches from licensed and unlicensed vessels (incl. foreign vessels).</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Use of anchor points and estimates of the level of uncertainty to determine likely extent of catches (incl. discards) obtained by commercial / recreational and subsistence fisheries.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">Officially reported landings
Artisanal catches: ratio of reported effort / surveyed effort from scientific surveys
National licensed industrial fleets and licensed foreign fleets : estimate of an average CPUE based on declared catch and effort data
Illegal catches (foreign origin): observed illegal catches in 2011 (source not cited in the paper) balanced by data from inspection activities (number of infringements in relation with inspection levels)
Discard date: results from scientific observations
Subsistence: assumptions on catches from specific surveys, and extrapolation
Recreational: estimates based on touristic frequentation of Senegal and % of those fishing, with assumption on daily catches</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Estimates of total catches by origin (National, foreign) and illegal catches in relation with assumed intrusion of unlicensed foreign vessels in the EEZ.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">Comprehensive approach
Attempt to provide estimates of total removals in a data-poor environment
Use of information from control authority (although it is weak)
Consideration of regulatory changes in estimates, in particular licensing arrangements of foreign vessels</td><td>Transparency of estimates
Paucity of robust anchor points
Insufficient characterisation of access by unlicensed foreign vessels (assume year round although stock abundance varies on a seasonal basis
No attempt to figure out whether illegal catches on regionally shared stocks are misreported, i.e. declared as being caught in Mauritania for example, or go unreported</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Bremner et al. (2009)</td><td>2009</td><td>Ministry of Fisheries, New Zealand</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of unreported bycatches in a NZ hoki fishery.
(context : in NZ, all bycatches of species covered by ITQ have to be reported and landed, by-catches of non-ITQ species have to be reported).</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>New Zealand West Coast hoki fishery</td><td>Industrial trawlers targeting hoki
(context : no small-scale fleet involved)</td><td>2005</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Underreporting of by-catch species.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Comparison between logbook catch and effort declarations of unobserved vessels and logbook declaration of observed vessels using information available on a tow by tow basis.
(context : some vessels are fully observed during their fishing trips)
Analysis of data took into account, through stratification, fishing conditions having a potential impact on bycatch composition and levels: gear characteristics, time of the day of tow, time in season, fishing area and processing facilities onboard (filleting fish, meal production).</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Register of licensed vessel and records of inspection (vessels and gear characteristics)
• Logbook declarations on a tow by tow basis
• Observer data on a tow by tow basis
• Quota availability and prices (incentives to misreport)</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Comparison between reported amounts of each bycatch species at fisheries level and estimates of the same.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Estimates of bycatches take into account technical aspects of each tow
• Estimates rely on factual information: no expert judgement</td><td>• Target species (hoki) excluded from estimates</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Limited to contexts of large-scale fishing operations with reasonable observer coverage and efficient enforcement system ensuring inspection of all vessels and registration of key information on vessels and gears characteristics.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Cisneros-Montemayor et al. (2013)</td><td>2013</td><td>UBC, Vancouver, BC, Canada</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimates of total removals (illegal and unreported catches, discards) of certain species.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Mexico EEZ</td><td>Commercial fishing, both artisanal and industrial, subsistence and recreational</td><td>1950-2010</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">“unreported legal” : non-quantified catches by fishers operating legally.
“unreported illegal” : non-quantified catches by domestic fishers operating illegally in any way.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Corrections to apply to official landing statistics as registered by FAO species by species to include catches that have not been taken into account. Use of anchor points and extrapolation methods.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Official reported landing statistics
• Linear extrapolation to correct missing data
• Information on fleets (target species, gear used)
• Available data on discarding rates of fishing vessels, both artisanal and industrial
• Expert opinion for amounts of unreported legal and illegal catches</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Total amount of catches by year and by species separating reported catches / unreported legal / unreported illegal / Unreported discards.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Comprehensive approach</td><td>• Large use of expert judgements to inform % unreported
• No reference to inspection data
• No assessment of incentives for illegal behaviours
• Simplistic confidence intervals (a flat +/- 15% across the time series)</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Clarke et al. (2009)	2009	Imperial College London
Study Objective		
Estimating legal and illegal catches of Russian sockeye salmon from trade and market data.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Eastern Russian waters	Sockeye salmon fisheries (driftnets)	2002-2006
Types of IUU activities considered by the study		
Unreported catches of sockeye salmon.		
Main methodology followed		
Utilisation of trade and market data (fisheries independent) using probabilistic models to determine likely level of catches originating in Eastern Russia.		
Data sources used		
• Available official data on catches by Russian vessels and on catches by Japanese vessels in Russian waters • Imports of sockeye salmon into East Asian countries from Russia (not the Russian export data) • Data on amounts of sockeye salmon traded on Japanese wholesale market • Expert judgements on presentations of products and on yield during processing operations (market data)		
Types of estimates / conclusions produced (incl. disaggregation levels)		
Comparison between Russian catches and imports from Russia / Comparison between all catches and market data (two independent estimates).		
Strengths	**Weaknesses**	
• Use of fisheries-independent data to build estimates • Limited use of expert judgement (for import model), but sensitivity analysis of expert judgement conducted • Transparent calculation of confidence intervals associated with estimates	• Fairly wide confidence intervals in estimates undermining possibility to conclude • Market model less precise than import model • Did not include in the models stock variations from one year to the next or potential double counting arising from inter-market transfers. However, bias discussed and found insignificant	
Transferability of method?		
Limited to case of species caught in an area and almost all exported to distant markets in countries with adequate recording of import and market flows.		

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Clarke et al. (2006)</td><td>2006</td><td>Joint Institute for Marine and Atmospheric Research, Univ. Of Hawai and National Institute of Far Seas Fisheries, Japan</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Global estimates of shark catches using trade data.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Global</td><td>All fishing activities involving trading of shark fins</td><td>1996-2000</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Unreported catches of sharks traded as fins.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Assessment of conversion factors from fin weight to live weight to estimate total biomasses of sharks sold through Asian markets based on trade data.
Use of probabilistic models to take into account uncertainty of variables used.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Scientific literature + specific measurements (conversion factor from fin weight to carcass weight)
• Custom data on quantities of shark fins traded through major Asian markets</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Estimates of corresponding shark biomasses by species and comparison between estimated biomasses caught and MSY</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Use of fisheries-independent data to build estimates of unreported catches
• Limited use of expert judgement, but sensitivity analysis of expert judgement conducted
• Transparent calculation of confidence intervals associated with estimates</td><td>• Do not include direct landings of National vessels into ports (not included in the scope of custom data)
• Fairly wide confidence intervals in estimates undermining possibility to conclude</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Limited to case of species caught in an area and almost all exported to distant markets in countries with adequate recording of import and market flows.</td></tr>
</table>

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Coll et al. (2014)</td><td>2014</td><td>IRD - France</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Estimates of total removals of fisheries products.</td></tr>
<tr><td>Geographical scope</td><td>Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>Spanish Mediterranean + Gulf of Cadiz</td><td>All activities whether commercial, recreational or subsistence</td><td>1950-2010</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Not specific: IUU includes all unreported catches, incl. discards, obtained through legal or illegal operations.</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">Corrections to apply to official landing statistics by species to include catches that have not been taken into account, whether landed or discarded. Use of anchor points and extrapolation methods.</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Official reported landing from various databases (FAO, GFCM, ICCAT, National and regional institutions
• Various literature sources for independent estimates of discards and unreported landings
• Stakeholders interviews for estimating extent of underreporting and of discards, plus identification of critical fisheries which deserve specific attention in relation with reporting</td></tr>
<tr><td colspan="2">Strengths</td><td>Weaknesses</td></tr>
<tr><td colspan="2">• Comprehensive approach
• Consideration of incentives to underreport, although very broad</td><td>• Large utilisation of expert judgment to support estimates
• Catches obtained illegally assumed not-reported (for ex. catches with illegal gears)
• No reference to inspection data
• Inclusion of discards</td></tr>
<tr><td colspan="3">Transferability of method?</td></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Coalition of Legal Toothfish Operators (2015)</td><td>2015</td><td>CCAMLR</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">To provide estimates of IUU toothfish in CCAMLR area to Scientific Committee meeting</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>CCMALR area</td><td>Toothfish</td><td>2014/2015</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Not specified individually for I, U and U, but presumed to focus on unregulated vessels</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Identification of IUU vessels and then direct observations and estimations for each vessel based on vessel speed, locations, steaming days, catching days, and catches/day etc, to calculate IUU catch</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Location and surveillance data
• Data from hauling of gillnets and catches onboard</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Identifies 1254 to 1500 tonnes of IUU catch
• Direct observations following arrests should mean estimates accurate</td><td>• n/a</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Transferable for this specific element of IUU behaviour but not practical more generally/widely.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Free et al. (2015)	2015	Rutgers University, New Jersey; Institute of Geoecology, Mongolian Academy of Sciences

Study Objective		
Evaluate the extent, character, and motivations of illegal gillnet fishing.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Lake Hovsgol National Park, Mongolia	Freshwater lake gillnet fishing	2009-2013

Types of IUU activities considered by the study

Illegal fishing by herders (non-recreational fishing has been banned since 2009).

Main methodology followed

Mixture of indirect and direct methods to determine how much illegal fishing still takes place, where and when it takes place, and attempt to determine the impact on fish populations

Data sources used

- Survey of lost fishing gear and gear fragments, providing indirect evidence for continued illegal fishing
- Interviews with herder households and rangers to determine motivations, which detected continued interest in spring spawning migration fishing,
- Analysis of trends in CPUE and mean length of fish, which failed to show any impact on the target species (grayling) but did show larger fish (roach, burbot, perch) declines
- Data-poor modelling to estimate M, Fmsy, and from previous acoustic surveys MSY

Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate

Quantities of abandoned gear were generated, but there is no attempt to relate this to actual fishing effort.

Strengths	Weaknesses
• mixed methods allows understanding of extent and motivation for IUU • essentially a survey technique in a data poor situation.	• No actual estimate of IUU

Transferability of method to other situations? Ability to contribute to a global estimate?

No. The method is very limited in its ability to determine actual IUU extractions, and is limited to reserve elements. The inability to calibrate lost gear (unlike the situation where you have fished areas outside a closed area; or where as in Agnew and Kirkwood the encounter with lost gear is actually modelled) is the problem.

Study reference	Year published	Responsible organisation
Funge-Smith et al. (2015)	2015	APFIC/FAO
Study Objective		
To show how characteristics of IUU vary within the Asia-Pacific region, to estimate scale (value and volume), to highlight IUU hotspots, to identify opportunities to combat IUU fishing, to provide a baseline for the past 6 years. Also considers drivers (governance and economic) of IUU, and provides an IUU risk assessment tool.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Asia Pacific region. Estimates made for 33 hotspots in the region	Foreign vessels or foreign beneficially-owned vessels (small-scale and medium-scale domestic vessels excluded) on basis that national action not cooperative action at regional level would respond to domestic issues	Information collection from 2009 to 2015, to estimate current figures for volume and value of IUU catch
Types of IUU activities considered by the study		
Focus on illegal and unregulated. See comment below on characterisation into categories and sub-criteria.		
Main methodology followed		
Hotspots of IUU fishing identified based on information from key 9 respondents, documented information and media reports. Characterisation approach taken (see table 3, section 2.1.2), with each hotspot considered for the extent of 6 categories of IUU fishing with sub-criteria of different types of IUU fishing activity under each category: encroachment; absence of authentic documentation; non-compliance with technical measures; illegal transhipment of landings; illegal catch of ETP species; degree of pre-meditation of IUU activity. (shore-based processing of IUU fish excluded). All catch from a vessel catching some fish illegally is considered illegal. In cases where IUU is identified as big problem in a fleet, whole fleet is considered as catching illegally. Values based on ex-vessel values not market prices, and taken from respondents or official sources. For some species/fleets, where landed prices were not available ex vessel values for different types of fish/fishing method were just assumed (and stated) and used with estimated volumes. For others an average break-even cost per trip was estimated for different sizes of vessels (based on assumed labour and operational costs) and applied to the number of trips (which in some cases were also estimated).		
Data sources used		
• Key respondents for hotspots and characterisation, backed up by additional information from… • media reports using web-searches of online papers and key words (with technical review of likely correctness of reports) • Official government websites and documents for information on hotspot fisheries • Trade data for some prices		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Identification of 33 hotspots, presented/analysed by area. Higher and lower estimates for tonnage and value of IUU provided for the 33 hotspots For each hotspot indication provided of which of the 6 categories/characteristics of IUU were prevalent. Of the total IUU catches fleets/hotspots, these were grouped into different characteristics of IUU catch: high volume low value, low volume high value, high volume high value, and low volume low value.		

IUU catch as a proportion of total catch by area provided.
Quality of estimate strongly impacted by many assumptions (some of which may be conservative but others of which may over-estimate (e.g. all catch of whole fleet considered as IUU when IUU issues identified in a hotspot).
IUU catch not disaggregated into elements within hotspot.

Strengths	Weaknesses
• Clearly states methodology, assumptions and limitations of the approach and methodology, and attempts to be conservative when factors are not known. • Requests for information about how confident responded were in the information may have weeded out less knowledgeable respondents. • Innovative methodology	• The assumptions and limitations associated with the methodology (as stated), which when considering their number are certain to make the estimates highly unreliable • Assumes that key respondents, documented information and media reports will capture most important hotspots and types of IUU • Number of respondents limited • Subjective nature of respondent views • Lack of disaggregation

Transferability of method to other situations? Ability to contribute to a global estimate?
Method transferable and able to contribute if 'hot spot' approach taken. But approach (lack of disaggregation) means would be difficult to measure change over time unless hotspots disappeared or un-selected in follow up assessment as the methodology does not identify IUU catch per se, only catch of an IUU segment in an area assuming that all fleet catch is IUU.

Study reference	Year published	Responsible organisation
Glazer et al. (2015)	2015	One Earth Future Foundation, OEF (NGO), Secure fisheries[5] is a US based programme of OEF

Study Objective

The report provides an in-depth background of Somali fisheries and documents the extent and impact of illegal (mostly poaching or fishing with expired or illegitimate licenses), unreported, and unregulated fishing on Somalis and their fisheries resources.

Geographical scope	Fishing activities included in the scope	Time period
Somali waters	• Vessels targeting tuna and tuna-like species (highly migratory species - HMS): (a) Asian or EU - flagged or owned - longliners and purse seiners, and (b) Small gillnet vessels fishing for coming from neighbouring countries such as Yemen and Iran • Vessels fishing for coastal pelagic or bottom-dwelling species, including lobsters and squid, a mix of industrial trawlers and coastal dhows that may target shrimp, squid, emperors, or snappers, and they represent diverse geographic range from Kenya to South Korea	Early 1980s to 2013

Types of IUU activities considered by the study

Catch reconstruction of foreign fishing including:

- Unreported and underreported fishing of foreign vessels in Somali waters, whether illegal or not
- Unregulated fishing by foreign vessels at least until Somalia declared its EEZ external limits and its coordinates in 2014

Main methodology followed

Estimate of foreign fishing in Somali waters by catch reconstruction using data sources below and following an established method for estimating IUU fishing outlined by Pitcher et al., 2002 (see related fiche) and based on the model developed by Pauly et al., 2014 for China distant fishing vessels (see related fiche).

Data sources used

- Estimated catch by IOTC-reporting nations in Somali waters based on the latitude and longitude reported with catches,
- Catch reconstruction using data found in scientific and media reports,
- Analysis of AIS vessel broadcast data that have date, time, and location stamps,
- Catch allocation estimates published by Sea Around Us (NGO), and
- Use of anchor points (data existence) to extrapolate catches for unknown years and a 95 % confidence intervals for the estimates

[5] http://securefisheries.org/, access: 16 March 2016.

<table>
<tr><th colspan="2">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="2">Main relevant estimates and conclusions produced by the authors:
Foreign vessels caught over 132 000 tonnes of ‘marine life’ [terms of the authors] in 2013, nearly three times the amount caught by Somali artisanal and subsistence fishers (40 000 tonnes)
Foreign fishing (both legal and illegal) must be limited, licensed, recorded, and regulated to facilitate the sustainable development of Somali fisheries as soon as possible (prior to the new Somali Fisheries Law in 2014, the legality of foreign fishing was less clear and licenses were frequently issued by local parties with no legal authority with the ignorance or the complicity of foreign fishing vessel owners)
Somalis could generate between USD 4 and 17 million in revenues each year from licensing foreign tuna longliners and purse seiners (estimated as a percentage of the annual gross market value of three commercially important tropical tuna species harvested in Somali waters)
Licensing revenue would be even greater if vessels from Iran and Yemen were licensed, flagged vessels have the largest foreign fishing presence in Somali waters</td></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Providing quantitative information on foreign fishing fleet activities in an area where illegal fishing in large volume has been known to occur for several decades although reduced in the late 2000s by a higher level of piracy</td><td>Assumption that all catch in catch areas straddling the Somali EEZ boundary are IUU</td></tr>
<tr><th colspan="2">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="2">Transferability of method to other situations? Yes, in terms of catch reconstruction.
Ability to contribute to a global estimate? Its contribution is more difficult to assess than its transferability potential. The extent of foreign fishing does not distinguish illegal and legal fishing in the estimated quantity of foreign fishing in Somali waters but focus on catch reconstructions.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Hentati-Sundberg et al. (2014)	2014	Stockholm Resilience Centre, Sweden
Study Objective		
Estimates of unreported / misreported landings.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Baltic Sea	Commercial fisheries targeting small-pelagics by Swedish vessels	1996-2009
Types of IUU activities considered by the study		
Underreporting and misreporting (species wise) of landings of herring and sprat by licensed vessels.		
Main methodology followed		
Reconstruction (GLM) of landing data using detailed logbook information with methodology incorporating information on gears and spatial distribution of tows. Based on effort data assumed to be reliable in the absence of incentive to misreport (no effort limits at that time, availability of effort control means through VMS and AIS).		
Data sources used		
• Officially submitted logbook data • Spatial distribution of abundance of target species using results from scientific surveys • Incentives to misreport based on quota availability, overcapacity and technological creep		
Types of estimates / conclusions produced (incl. disaggregation levels)		
Estimated actual landings of each species for the whole SWE fleet, compared with official landing data.		
Strengths	**Weaknesses**	
• Based on factual information only. No expert judgments • Inclusion in the model of spatial dimensions of the fisheries (i.e. cpue are not uniformly distributed across the fishing area) • Pre-assessment of incentives to misreport and adjunction of relevant variables in the models.	• Estimates based only on modelling of logbook data. No anchor points, i.e. data from fully inspected vessels, included to calibrate models	
Transferability of method?		
Limited to case of fisheries involving only licensed vessels subject to logbooks, with no significant discarding practices (the small pelagic fishery in the scope of the study is industrial with all catches assumed to be landed).		

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Kleiven et al. (2012)</td><td>2012</td><td>Institute of Marine Research, Norway</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimation of total catch of red listed species</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>SE Coast of Norway</td><td>Commercial and recreational pot fisheries targeting European lobster</td><td>2008</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Underreported commercial lobster catches (deemed as IUU activities) and recreational lobster catches</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Probability-based strip transect surveys used to count buoys in combination with CPUE data obtained from volunteer catch diaries, phone interviews and questionnaires.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• At-sea weekly surveys to records names of owners of traps (commercial fishermen have to mark their buoy with the registration number, recreational fishermen must mark their buoy with their names and address)
• Surveys of commercial and recreational fishermen (panels of volunteers supplying detailed fishing diaries to science on a confidential basis, i.e. not shared with enforcement authorities)</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels)</th></tr>
<tr><td colspan="3">Total estimated lobster catches from commercial and recreational fishermen compared with official records.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Based on factual information - no use of expert judgment
• Fisheries-independent estimate of fishing effort based on at-sea surveys)
• Representativeness of panels tested</td><td>• Time consuming, costly and weather dependant method (surveys at sea)
• No attempt to quantify catch of lobster outside the legal season</td></tr>
<tr><th colspan="3">Transferability of method?</th></tr>
<tr><td colspan="3">Limited to localised, both in time and in space, passive gear fisheries with prescriptions on the marking of buoys. (the Norway lobster season is open two months per year)</td></tr>
</table>

Study reference	Year published	Responsible organisation
Leitão et al. (2014)	2014	Centro de Ciências do Mar, Portugal UBC, Vancouver, BC, Canada
Study Objective		
Reconstruction of likely total catches in waters of Portugal mainland.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Portugal mainland EEZ	Commercial fishing, recreational and subsistence fishing	1938-2009
Types of IUU activities considered by the study		
Unreported discarded catch from commercial fisheries, unreported recreational / subsistence catch.		
Main methodology followed		
Disaggregation of official reported catch by fleet segment and estimates of total amounts discarded based on available discard rates.		
Data sources used		
• Official reported landings • Grey and scientific literature for estimates of amounts of discards proportional to catch		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Total removal by licensed fleets and recreational subsistence fisheries by gear types and species over the 1938-2009 period		
Strengths	**Weaknesses**	
• Comprehensive approach	• Do not consider variation over time of incentives to discards • Assume discards rates did not change over time • No specific estimates of extent of illegal fishing • Assume official reported landings as accurate	
Transferability of method to other situations? Ability to contribute to a global estimate?		
Yes.		

Study reference	Year published	Responsible organisation
Lescrauwaet et al. (2013)	2013	Flanders Marine Institute VLIZ, Belgium
Study Objective		
Reconstruction of likely total catches of Belgium vessels and of total catches within area under jurisdiction of Belgium.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Fisheries under competency of Belgium	Commercial fisheries, subsistence fisheries	1929-2010
Types of IUU activities considered by the study		
Unreported amounts of discarded fish. Underreported catches by commercial vessels.		
Main methodology followed		
Corrections to apply to official landing statistics by species to include catches that have not been taken into account, whether landed or discarded.		
Data sources used		
• Official reported landings (ICES database) • Ancient National reports on fisheries (from 1929) • Grey and scientific literature for estimates of amounts of discards proportional to catch • Estimates of catches of commercial and recreational fleets not mandated to report		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Total removals identifying separately underreported landings and discarded amounts		
Strengths	**Weaknesses**	
• Comprehensive approach • Attempt to quantify underreporting in commercial fisheries	• Do not consider variation over time of incentives to discards • Assume discards rates did not change over time	
Transferability of method to other situations? Ability to contribute to a global estimate?		
Yes.		

Study reference	Year published	Responsible organisation
MRAG (2005a)	2005	MRAG Ltd for the UK's Department for International Development (DFID), with a support from the Norwegian Agency for Development Cooperation (NORAD)

Study Objective

To better understand and identify IUU fishing primarily in waters under the jurisdiction of developing countries and on the high seas and analyse their economic, social, environmental, ecological, biological, health and nutritional impacts on these countries.

Geographical scope	Fishing activities included in the scope	Time period
EEZ (mostly EEZ of developing countries) and high seas	• 'Big issue' fisheries: a) high seas fishing targeting 1) tuna, tuna-like species (gear: pelagic longline and seines), and small pelagic fish (Chilean Jack mackerel caught with seines and pelagic trawls), 2) sharks (gear: pelagic longline), 3) groundfish (toothfish caught with demersal longline, cod caught with bottom trawls, redfish caught with bottom/semi-pelagic trawl, orange roughy) and 4) cephalopods (squid caught with jig) and b) Fishing activities in EEZ: cod, sturgeon, holothurians and abalone • 10 case studies focusing on IUU fishing in Guinea, Liberia, Sierra Leone, Angola, Namibia, Mozambique, Kenya, Somalia, Seychelles, Papua New Guinea waters	Year 2002 mostly

Types of IUU activities considered by the study

Illegal (for instance unlicensed fishing in EEZ), unreported and unregulated (for instance on the high seas) fishing activities.

Main methodology followed

- Ad-hoc bottom-up approach (the core method applied by the author in the study):
  - adding estimates of IUU catches from more detailed information at a lower scale, that is from the case studies (case studies estimates) and estimates of IUU catches from the high seas and EEZ not covered by the case studies ('big issue' estimates)
  - Own estimates in values: based on quantities in tonnes whole weight equivalent converted into first sale values
  - Predicting IUU catch essentially in sub-Saharan Africa and outlying islands by extrapolating from the case studies and applying a predictive model by vulnerability analysis
- Top-down approach: based on using global estimates of the proportion of unreported catch

Data sources used

- For the analyses of the big issue fisheries: literature review of press articles, reports, web pages, RFMO and national data
- Series of case studies by countries – collected information: ad hoc reports on IUU fishing activities to estimate IUU losses in values
- Vulnerability model extrapolated from the case studies findings

<table>
<tr><th colspan="2">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="2">Bottom up approach:
Total loss to IUU fishing in the case studies was USD 372 million: 19% of the total value of the catch; or 23% of the declared value of the catch (likely to be an estimate for 2003 but year unclear). Two groups of issues: 1) shrimp fisheries (Guinea, Sierra Leone, Liberia, Mozambique) suffered IUU fishing from industrial trawling vessels from distant water fishing fleets and 2) environmental impacts of tuna fishing for the previously mentioned countries and Somalia such as longliners targeting sharks
Annual value of high seas IUU catches in USD in the ‘big issue’ fisheries: 1,244 million (likely to be an estimate for 2003 but year unclear)
Annual value of IUU catches in EEZ in USD in the ‘big issue’ fisheries (cod, sturgeon, holothurians, abalone): 255 million (likely to be an estimate for 2003 but year unclear)
By applying a predictive modelling, there seems to be a good linear relationship between governance and the % of IUU activities in EEZ (% IUU = 0.0149 – 0.3161 x governance index), the one-parameter model estimated the value of IUU catch in the Sub-Saharan region (in the EEZ of the coastal African countries) to be USD 0.9 bn (95% c.i. $0.4 - $2.3bn), which represented 16 % of the total catch value for these countries or 19 % of the declared catch in 2003
Top-down estimate: extrapolated from the percentage of IUU catch in the sub-Saharan Africa region – see above, 19% (16 million tonnes, USD 9.5 bn) to 30% (a) of the global marine catch (84 million tonnes, USD 49.92 billion - FAO estimates) are IUU fishing in 2002, which are more likely overestimates given the likely skewed distribution of IUU catch as a percentage of legal catch by state according to the authors [a :the higher percentage, 30%, originates from an estimate of unreported catch as a proportion of the total global reported catch from Pauly and MacLean, 2003[6]].</td></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Relatively sound overall picture of global IUU marine fishing with detailed findings through the case studies
A detailed section presenting the applied methods and discussing the limits to build overall estimates of IUU catch from a collection of incident reports</td><td>Limited global scope: the report provides a global estimate of IUU fishing based on only selected fisheries and extrapolation (the authors are however aware of the limit of their method and discussed it in the report).</td></tr>
<tr><th colspan="2">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="2">Transferable, however the applied method has been improved in more recent studies; and
Provides a global estimate itself</td></tr>
</table>

[6] Pauly D. and J. Maclean (2003) In a perfect ocean. Island press.

Study reference	Year published	Responsible organisation
MRAG (2015)	2015	FAO / BOBLME secretariat

Study Objective

To estimate volume and value of I, U, and U fishing by country and at regional level for the Bay of Bengal Large Marine Ecosystem Countries.

Geographical scope	Fishing activities included in the scope	Time period
Bay of Bengal Large Marine Ecosystem. Sub-set of countries in S and SE Asia from Pakistan in west to Vietnam and Philippines in East	Marine. All species in theory (but limited by risk assessment data available).	1990- 2013

Types of IUU activities considered by the study

illegal and unreported fishing in 17 countries.

Main methodology followed

Anchor point and influence methodology used in Agnew et al 2009, Ainsworth and Pitcher (2005) and Varkey et al(2010). Risk based framework, using qualitative assessment of factors influencing risk and contributing to IUU, anchor points, and likelihood-impact framework. Steps included:

- Base level data collection on catches
- Data collection on IUU influencing factors
- Breakdown of national catches by fishery/fleet segment
- Risk assessment approach
- Turning qualitative estimate of risk in quantitative estimate
- Development of a regional IUU database

Data sources used

- Official catches by country using FAO FishStat
- Price data (to generate values of IUU catch) e.g. from Infofish, Eurofish
- Bibliographic references and grey lit for IUU influencing factors and events (press, RFMO IUU records and reports)
- Use of locally based experts to break down national catches in fleets/fisheries
- Expert judgement for assessment of likelihood (based on value, access to resource, multiple gear access to resource, market access/demand, regional coordination), and use of other published sources on corruption, prosecution ratios, levels of sanctions.
- Expert judgement for assessment of impact (on gears impacts, resilience of species, resilience of habitats, high tropic level species)
- Qualitative risk assigned quantitative level based on risk level and expert judgement

Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate

Separate estimates for unreported and illegal fishing by volume and value by country, and species group.
Upper and lower estimates provided.

Strengths	Weaknesses
• Clear articulation of methodology • Separate estimates for illegal and unreported. • Good disaggregation by country and species	• Size/range of upper and lower estimates • Gaps in price data and need to use averages • Inherent weaknesses in expert judgement approach • No clear specification of study weaknesses/limitations

Transferability of method to other situations? Ability to contribute to a global estimate?

Transferable and has ability to contribute to global estimate.

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>MRAG (2016)</td><td>2016</td><td>FFA</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">To quantify the volume, species composition and value of IUU fishing in Pacific tuna fisheries.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Pacific region: area below 20oN, east of 130oE and north of the southern boundary of the WCPFC Convention area, and east to the eastern boundary of the WCPFC Convention boundary, including EEZs of both FFA and non-FFA member states and areas of high seas. Excludes the Indonesian and Philippines EEZs.</td><td>Estimates of IUU volume and value were developed for each of the three main fishing sectors - purse seine (PS), tropical longline (TLL) and southern longline (SLL) – and then aggregated to produce an overall regional estimate for Pacific Islands region tuna fisheries</td><td>Estimates are ‘typical’ levels of annual IUU fishing across each category for the period encompassed by the study (2010-2015)</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">(i) unlicensed/unauthorised fishing, (ii) catch misreporting, (iii) non-compliance with other license conditions (e.g. FAD fishing during the purse seine closure period) and (iv) post-harvest risks (e.g. illegal transhipping).</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">A bottom up approach which aimed to arrive at regional-scale estimates of the volume and value of IUU fishing by first breaking down the ‘IUU problem’ into discrete quantifiable units, based on identified risks, and then aggregating these up to produce a regional scale estimate. The approach took account of all of the available information to generate ‘best estimate’ values of IUU activity for each risk in each sector, as well as minimum and maximum range values. Approach used in study was similar in part to the ‘anchor points’ approach described in Ainsworth and Pitcher (2005) (and later used by Agnew et al, 2009,) in that authors assigned ‘best estimates’ and minimum and maximum ranges of known IUU activities and then used Monte Carlo simulations to determine the likelihood that IUU fishing would be within a certain range. However, the approach was amended for this study based on the nature of the assignment (a ‘snapshot’ estimate of IUU activity, rather than a historical time series) and the nature of the risks and available information (for example, the availability of data for some risks allowed for more direct estimation of ‘best estimates’ and ranges). Five main steps:
Identifying IUU risks
Estimating best estimate and min and max range
Assigning likely probability distribution
Monte Carlo simulations
Quantifying ex vessel values, economic rent and value added</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">National risk assessments from 10 countries
Country visits to collect national level data
WCPFC/SPC catch data
Fleet economic data collected by PNA
For unlicensed fishing: VMS, aerial and surface surveillance, observers, media, FFA member site visits. FFA compliance index data</td></tr>
</table>

- For Unregulated fishing: aerial and surface surveillance, observer sightings, previous risk assessments and anecdotal information
- For Mis-reporting: comparisons of observer vs logsheet reporting
- For Fishing on FADs: observer data and earlier studies (Hare et al, 2005)
- For Fishing inside closed waters: VMS data and anecdotal report
- For Shark finning: regional observer data
- For Use of wire traces in LL: isolated boarding and inspection reports, dockside monitoring reports and observer reports
- For illegal transhipping: expert judgement
- For all of the above estimates were ground-truthed at a regional workshop

Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate	
Volume and value by type of IUU (4 types see above), species, and fleet segment, along with economic rent and value added.	
Strengths	Weaknesses
• Clear presentation of all methodology and data sources • Development of a framework for the quantification of IUU fishing in Pacific tuna fisheries and the design of a basic model that can be refined and updated over time as IUU risks change and better information becomes available • Recognition/discussion on possible double counting • Use of study outputs to make recommendations on ways of reducing IUU fishing. Of practical benefit to WCFPC	• Some ranges between upper and lower limits large (others less so). Large limits were linked to greater levels of uncertainty • Some double counting? (but risk acknowledged) • Estimate not a snapshot/single year due to different dates of data used but 'typical' levels of annual IUU (this may be a strength also).
Transferability of method to other situations? Ability to contribute to a global estimate?	
Yes, but assuming same level of data availability which may not be the case in non-tuna fisheries. Could contribute to global estimate (for tuna fisheries in Pacific region).	

Study reference	Year published	Responsible organisation
NASCO (2007)	2007	North Atlantic Salmon Conservation Organisation (NASCO)
Study Objective		
Better knowledge of illicit fishing of wild Atlantic salmon to enhance the conservation of the species in waters under the jurisdiction of NASCO parties (the ad hoc report consists of presentations made by a selection of NASCO parties at the 2007 Special Session of NASCO on Unreported Catches).		
Geographical scope	**Fishing activities included in the scope**	**Time period**
North Atlantic waters of NASCO parties focusing on rivers, estuaries and coastal waters under the jurisdiction of the EU (Denmark in respect of the Faroe Islands and Greenland, Ireland and the UK), Canada, Iceland, Norway, Russia and USA	Ireland: commercial and recreational fishing (rod fishing) UK: rod catch, net and trap licensed fishing and unlicensed fishing in rivers and some coastal areas Canada: recreational and aboriginal fisheries in river, estuarine and coastal areas (gear not specified) Denmark: recreational fisheries in Faroese rivers (gear unspecified) Iceland: salmon angling and rod fishing USA: commercial and recreational (angling) fisheries Norway: legal and illegal river fishing mainly by anglers, by-catch of salmon in gill net and drift net fishing Russia: illegal catch of salmon in rivers and legal coastal and river fisheries by net and rod	Different time period applied for each country, for instance: Ireland: 1970 – 2005 USA: 2006 Russia: long term analysis with a case study (Umba river) focusing on 2006 data
Types of IUU activities considered by the study		
Unreported fishing of Atlantic salmon when or where catch of Atlantic salmon is authorised. Illegal fishing of Atlantic salmon when or where catch of Atlantic salmon is not authorised.		
Main methodology followed		
Unreported catch from legal fishing and illegal fishing estimated by public fisheries officers based on sources cited below; in Ireland, use of a raising factor to estimate unreported catches from recreational fisheries using a range; in the UK, use of a catch reminder mechanism in rod angling; in Russia a mathematical simulation model was used for estimating illegal catch on one of the rivers (the Umba).		
Data sources used		
• Surveys, local observations and reports from recreational fishing associations (and commercial fisheries using logbooks for Ireland) • Local knowledge and past estimates when lacking information		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		

<table>
<tr><td colspan="2">Estimates of illegal fishing and unreported catch of Atlantic salmon in tonnes or/and in percentage of total catches in the investigated legal fisheries (for instance, in 2006 in Norway).
Most countries conclude that despite all efforts to develop effective methods for estimating the unreported catch, estimations have not so far been very accurate, with estimates relying mainly on the local knowledge of fisheries, data from logbooks and catch statistics. Ireland: estimates of unreported catch were a relatively good approximation for most years although the actual fluctuations over time cannot be ascertained; England and Wales: progress in improving catch reporting and fighting illegal fishing reduced under-reporting.</td></tr>
<tr><td>Strengths</td><td>Weaknesses</td></tr>
<tr><td>States methodology, assumptions and limitations of the approach and methodology, and attempts to be conservative when factors are not known.</td><td>Not a common methodology and time period applied between the countries which makes difficult to provide an overall conclusion on the findings
Data are aggregated (low level of detail)</td></tr>
<tr><td colspan="2">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="2">Yes, to estimate unreported catches in recreational fisheries in developed countries (for instance, the Russia simulation model, the raising factor applied by Ireland, the catch reminder mechanism applied by the UK).</td></tr>
</table>

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Pauly et al. (2014)</td><td>2014</td><td>UBC, Vancouver, BC, Canada</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Estimates of Chinese long-distance vessels catches worldwide.</td></tr>
<tr><td>Geographical scope</td><td colspan="2">Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>Global</td><td colspan="2">Distant water commercial fisheries
Retained catches (=landings) only</td><td>2000-2011</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Not specified: the paper documents possible catches of China distant-water fleet whether obtained legally or not. However, the study raises significant underreporting issues.</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">Retained catches estimated by establishing the presence and numbers of Chinese vessels in EEZ of 3rd countries multiplied by average catches by vessel types (5 types).</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Anecdotal information on activities of distant water vessels flagged to China in different countries
• Average catches per vessel types as estimated by Lam et al. (2011)</td></tr>
<tr><td colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</td></tr>
<tr><td colspan="3">Estimates of catches of the long distance fleet flagged to China compared to official landing data indicating likely considerable underreporting.</td></tr>
<tr><td>Strengths</td><td colspan="2">Weaknesses</td></tr>
<tr><td>• Global range of estimates</td><td colspan="2">• Chinese vessels defined as those with officers and crew from China. No link with flag vessels established
• Possible issues of double counting (same vessels present in different areas)
• High reliance on expert judgment to estimate numbers of vessels by type
• Inability of method to distinguish between legal and illegal activities</td></tr>
<tr><td colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="3">Method can possibly be used to estimate catches of long distance fleets.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Pauly and Zeller (2015)	2015	Sea Around Us (research initiative at The University of British Columbia)

Study Objective

Present the authors' concept, method and data sources applied for Sea Around US recent catch reconstructions; for instance in Pauly and Zeller (2016).

Geographical scope	Fishing activities included in the scope	Time period
Marine waters	Catches of marine fishes by fishing countries in their EEZ and inshore fishing areas (coastal area to a maximum of 50 km from the coast or to 200 m depth, whichever comes first) Catches that are not associated with tuna and other large pelagic fishes, but taken by fishing countries outside their domestic waters Catches of large pelagic fishes (mainly tunas) – see cell 'main methodology' for the segments included	1950- 2010

Types of IUU activities considered by the study

Focusing on unreported/under-reported catches including discards.

Main methodology followed

1. Identification, sourcing and comparison of baseline reported catch times series, i.e., a) FAO (or other international reporting entities) reported landings data by FAO statistical areas, taxon and year; and b) national data series by area, taxon and year
2. Identification of sectors (industrial, artisanal, subsistence, recreational), time periods, species, gears etc., not covered by (1), i.e., missing data components. This is conducted via extensive literature searches and consultations with local experts
3. Sourcing of available alternative information sources on missing data identified in (2), via extensive searches of the literature (peer-reviewed and grey, both online and in hard copies) and consultations with local experts. Information sources include social science studies (anthropology, economics, etc.), reports, colonial archives, data sets and expert knowledge
4. Development of data 'anchor points' in time for each missing data component, and expansion of anchor point data to country-wide catch estimates
5. Interpolation for time periods between data anchor points, either linearly or assumption-based for commercial fisheries, and generally via per capita (or per-fisher) catch rates for non-commercial sectors;
6. Estimation of total catch times series, combining reported catches (1) and interpolated, country-wide expanded missing data series (5)
7. Quantifying the uncertainty associated with each reconstruction [including conservative estimates of discards for foreign landings from the discarding rates of the domestic fisheries (ghost fishing, under-water discards and net-mortality not counted). (based on Pauly and Zeller, 2015)

Data sources used

- FAO and national data
- Grey literature
- Interviews

<table>
<tr><th colspan="2">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="2">Method to estimate illegal fishing of foreign fishing in non-domestic EEZ: distant water fishing fleet size multiplied by appropriate catch per unit of effort rates leading to an estimate of illegal catch in these EEZs.</td></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Reconstruction method in constant improvement from the method applied by Pauly in 1998 (see next cell below)</td><td>From the presented method, it does seem to take into account only illegal fishing estimate from foreign industrial fishing fleet
Although catches in inshore fishing areas are taken into account, it is unclear in the method how IFA relates to recorded catches in territorial seas (reminder: EEZ areas exclude territorial seas – UNCLOS, article 55)</td></tr>
<tr><th colspan="2">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="2">Yes, to both, although the method is based on reconstructing global catches by (1) adding unreported fishing estimates and (2) illegal fishing estimates of foreign fishing in non-domestic EEZs. Authors are aware that the approaches used are preliminary and further improvements are needed to improve the accuracy of the catch reconstructions.</td></tr>
</table>

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Payne et al. (2005)</td><td>2005</td><td>Imperial College</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Stock assessment of toothfish around the Falkland islands.</td></tr>
<tr><td>Geographical scope</td><td>Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>SW Atlantic</td><td>Commercial longline fishing for toothfish</td><td>1994-1996</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Illegal (unlicensed and unreported) fishing.</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">Age Structured Population Model (ASPM) tuned to CPUE from known commercial vessels, which was allowed to estimate missing catch for a number of defined years.</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Commercial CPUE
• Commercial known reported catches
• Life history parameters, etc, to create population model</td></tr>
<tr><td colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</td></tr>
<tr><td colspan="3">The known commercial CPUE shows a marked reduction in the mid 1990s which does not fit the known commercial data. When allowed to estimate unknown catches the model does very well, predicting catches consistent with anecdotal reports at the time.</td></tr>
<tr><td colspan="2">Strengths</td><td>Weaknesses</td></tr>
<tr><td colspan="2">• Objective, analytical, based on known reported data
• Cross-validated with anecdotal information from expert sources, but not reliant on them</td><td>• Single species
• This, and other assessment models using multiple data sources (eg CASAL: NIWA, New Zealand) are capable of estimating unknown quantities, but they require some fixed points from which to do this, or they end up explaining all variability between observed and estimated quantities in terms if missing catch; this is the reason that random walk on catchability needs to be constrained between some parameters.</td></tr>
<tr><td colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="3">Very transferable, but in specific situations. Similar approaches were taken for cod in the north sea, which used a fishery-independent index tuned stock assessment model to calculate the difference between predicted and observed catches during a period in the early 2000s when there were very significant underreported catches (see Agnew, paper to FAO workshop, February 2015).</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Pham et al. (2013)</td><td>2013</td><td>Universidade dos Açores, Portugal</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Reconstruction of statistics on total removals of fisheries products.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Waters around Azores archipelago</td><td>All commercial fishing activities, including foreign vessels, recreational and subsistence fishing
All species, including marine mammals</td><td>1950-2010</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Study considers as IUU all unreported catches, incl. discards, whether obtained legally or illegally.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Corrections to apply to official landing statistics by species to include catches that have not been taken into account, whether landed, discarded or used for other purposes (e.g. bait).</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">Official landing statistics gathered from various local and international sources
Records of scientific observations on discarding rates of some fleet segments
Records of scientific observations on amounts of bait used for tuna fishing
Existing surveys of recreational fishing and of shore fishing in Azores</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">Total amounts of estimated catches by species, whether landed or discarded (not precise).</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">Comprehensive approach
Attempted to avoid double-counting by assuming that catches obtained by foreign fleet are reported elsewhere (e.g. ICCAT; Russian statistics)</td><td>High reliance on expert judgments
Unclear method for calculating confidence intervals of estimates
Consider as IUU all quantities not reported in official statistics
No specific estimates of extent of illegal fishing
Assume official reported landings as accurate</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Piroddi et al. (2015)</td><td>2015</td><td>JRC, Ispra, Italy
UBC, Vancouver, BC, Canada</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Reconstruction of statistics on total removals of fisheries products and on historical CPUE of the fleet.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Fisheries under the competency of Italy</td><td>Commercial fisheries (artisanal and industrial), subsistence and recreational, incl. discards</td><td>1950-2010</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Study considers as IUU all unreported catches, incl. discards, whether obtained legally or illegally.</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Corrections to apply to official landing statistics by species to include catches that have not been taken into account, whether landed or discarded.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Official National landing statistics
• Evolution of the regulatory framework
• Ad-hoc scientific information on discard rates
• Existing surveys of recreational fisheries
• Records of infringements appearing in press reports</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">Unreported catches by sector and by species.
Reconstructed cpue based on reconstructed catches and inferred levels of vessels activities.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Comprehensive approach
• Include considerations on evolution of regulatory framework for incentives to IUU fishing
• Attempt to separate catches from illegal activities (underreporting)</td><td>• High reliance on expert judgments
• Assume official reported landings as accurate</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Pitcher et al. (2002)	2002	UBC
Study Objective		
Method of anchor points and influence factors.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Global	Any IUU in Iceland and Morocco	1950 – 2000
Types of IUU activities considered by the study		
Potentially all; but in the examples given, Iceland – discarding, Morocco discarding and unreported landings.		
Main methodology followed		
Identification of some fixed points (studies of discarding, estimates of illegal activities), matching to assumed influence factors (management regimes, changes).		
Data sources used		
• Official reported landings • Estimates of discards and unreported catches • Information to drive interpolation (changes in regimes; anecdotal reports)		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Disaggregation follows the resolution of the data as does the likely quality of the estimates; in the case of Morocco, it was for coastal, industrial and foreign fleets. No information on discarding or unreported catches are available for the foreign fleets but the comment on the (large) interpolated catch from foreign fleets is "assumed intermediate between coastal (where there is an estimate) and industrial (where there is an estimate). Although context is different the incentives to cheat and opportunities to sell fish are as high as with the Moroccan fleet". Accuracy of sources difficult to check because references not accessible.		
Strengths	**Weaknesses**	
• Produces estimates for years and fleets for which there is no information. • Transparent derivations	• The assumptions for interpolations are transparent, but there is no way of really checking on the quality of the resultant estimates of IUU or the reasonableness of the estimates. • References are of highly variable quality, and in many cases are anecdotal/expert opinions. There are ways for correcting for this introduced in some later applications of the methods (systematic expert opinion) but this appears to be rarely used.	
Transferability of method to other situations? Ability to contribute to a global estimate?		
Quality and reliability of estimates, particularly historical time series, is generally low with this method. However, it has very broad application, and has been repeatedly been used by UBC and other authors. Could contribute to country calculations contributing to a global estimate.		

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Plagányi et al. (2011)</td><td>2011</td><td>University of Cape Town</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Assessment of level of IU (illegal, unreported) catches of Abalone in South Africa.</td></tr>
<tr><td>Geographical scope</td><td>Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>South Africa</td><td>Commercial fishing</td><td>1994-2008</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Illegal and unreported: essentially all Illegal since all reporting is required.</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">Multi—method approach: modelling abalone population with a spatial and age structured model, including in the model illegal catches tuned to law enforcement data, cross validation with trade data.</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Enforcement data generating confiscations per unit of policing effort
• Population model data for abalone (biological; known commercial catches and GLM-standardised CPUE; recreational catches estimated from telephone surveys; diving surveys) expressed spatially
• Global trade data on abalone</td></tr>
<tr><td colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</td></tr>
<tr><td colspan="3">Spatial estimates of IU fishing. Quantitative estimate good quality, and IU estimate over a large number of years, peaking at 1000% of legal catch.</td></tr>
<tr><td colspan="2">Strengths</td><td>Weaknesses</td></tr>
<tr><td colspan="2">• Uses multiple data sources, generating realistic IU estimates. This is the major strength – it does not rely just on trade data or just on one other assumption such as anecdotal reports
• Very robust analytical model generating confidence intervals at relevant spatial scales
• Cross-referencing with trade data allows reality check without relying on trade data for information</td><td>• May need there to be high-profile resource such as abalone to have good estimates of illegal activity from compliance authorities
• Needs good stock assessment data to generate underlying ASPM, including fishery-independent surveys</td></tr>
<tr><td colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="3">Yes, should be applicable in other situations. However, this type of approach has not been very widely used, because it is data intensive.</td></tr>
</table>

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Polacheck (2012)</td><td>2012</td><td>CCSBT</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Exploration of different hypotheses for the source of the under-reported SBT catches during the 15 years 1990 – 2005.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>SBT range (Pacific)</td><td>Longline catches</td><td>1985-2005</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Illegal (fishing in closed areas and over-quota catches by Japan, a Member of CCSBT); unregulated (fishing by Indonesia, Korea, while non-Member); unreported (under-reporting of catches by Indonesia).</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Comparison of Japanese import statistics and market statistics, supported by analysis of logbook data and in the case of Indonesia, port sampling.</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Import statistics
• Market (auction) statistics
• Sampling</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">Estimates on an annual basis of total IUU catches (up to 200% more than the reported catch / TAC; 66% of the total catch being IUU), of good quality. Some disaggregation by area, but little understanding of actual size composition. Some hypothesis that catches misreported as bigeye.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Data are independent of the fishers undertaking the IUU
• Japan only importing country</td><td>• Market data very difficult to acquire
• Lags between catches and marketing
• Inability to capture any fish retained for domestic consumption in eg Indonesia
• Inability to easily distinguish between farmed and IUU</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">As with other trade data analyses, this analysis by CCSBT relied on a limited number of markets and is not necessarily transferrable to other situations unless there are similarly high value single species identified in market/trade data.</td></tr>
</table>

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Pramod et al. (2014)</td><td>2014</td><td>WWF sponsored UBC research</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Estimation of illegal fish imported to USA</td></tr>
<tr><td>Geographical scope</td><td colspan="2">Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>USA imports</td><td colspan="2">All imports to the USA – estimates are not made of illegal and unreported catches in domestic waters</td><td>2011</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Illegal and Unreported (not unregulated) – but not disaggregated in final estimates</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">For the top 10 countries exporting to the USA and the top 3 species categories / products exported by each, an IU estimate was made on the basis of that fishery, not the exact exported fish. For each of the 30 fisheries the normal UBC method was used, using 180 sources including 41 interviews (32 confidential).</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Published reports of illegal and unreported fishing, Anecdotal information, confidential interviews in data poor situations.
• Reported catch statistics
• Trade flow data to identify products imported to USA from different countries</td></tr>
<tr><td colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</td></tr>
<tr><td colspan="3">IU estimates (combined – not disaggregated by type of IUU)</td></tr>
<tr><td colspan="2">Strengths</td><td>Weaknesses</td></tr>
<tr><td colspan="2">• Because no temporal trends are calculated, the results of this study suffer less from the normal “anchor/influence” method interpolations, and are probably more robust. Furthermore, the target is imports into one country, rather than estimates of IUU fishing in a particular country, which is a change in methodology.</td><td>• Lack of transparency on some estimates, low quality/reliability of some sources (press, anecdotal) and combination of estimates with differing quality.</td></tr>
<tr><td colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="3">Yes. One of the more rigorous studies of its type to date, though still prone to multiple assumptions not so susceptible to interpolation issues. Also provides estimates for some of the most widely traded fish (given imports to a major state such as USA). Similar study for the EU could be combined with this to provide estimate for more than 50% of the world’s traded fish.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Restrepo V. R. in OECD (2004) – section 'Compiling evidence' [to quantify IUU fishing] – chapter 9	2004	ICCAT Secretariat
Study Objective		
Presenting the process applied by ICCAT to estimate unreported catches using a case study.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
ICCAT area	Tuna fishing activities (case study: Atlantic bluefin tuna, BFT)	Case study: 1994 - 2002
Types of IUU activities considered by the study		
Unreported catches		
Main methodology followed		
Comparing catches and trade data • The ICCAT catch database contains a special code 'NEI' (not elsewhere included). For the purpose of the case study, NEI correspond to unreported catches. It is then up to the ICCAT Commission to decide whether or not the unreported catch is an evidence of IUU fishing. NEI codes may be assigned to flag State to distinguish unreported catches and reported catches by that same flag State • NEI calculation: NEI [from a country x] = A-B-C-0.8D (A: catch reported [by a country] to ICCAT, B: imports to USA, C: imports to Japan from wild fish, D: imports to Japan from farmed fish), when the NEI is negative, the figure is considered corresponding to unreported catches from the country x. 0.8 corresponds to the bluefin fattening factor (25 % gain weight for the initial weight the tuna entering a farm) • Conversion factors are applied to estimate live weights (to reach the round weight: belly meat from wild tuna, 10.28; dressed weight – fish gilled, gutted, headed and definned, 1.25; fillet, 1.67; gilled and gutted weight: 1.16; other products, 2.0) • Double counting is avoided (see strengths below), by not applying conversion factors for belly weight for farmed fish • Application of the above formula not fixed: data are often aggregated among gears and use of NEI combined catches from several countries to reflect practices of fishing and fish farming at the studied time period		
Data sources used		
Case study: data from the BFT statistical document programme (SDP): fresh and frozen BFT and farmed BFT (from 2003), flags of vessels, vessel characteristics, area of catch, type and amount of product traded, ICCAT statistical document validated by government officials to pass import customs, bi-annual ICCAT contracting party summary report on tuna imports.		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
• 50 – 60 % of BFT catches are traded internationally • 1 to 5 % of BFT catches are estimated to be unreported from the method applied above (5-10 % in the early 1990s, rose to over 20 % in in the late 90s and around 5 % in the early 2000 • Although these estimates cannot be fully accurate, a useful tool to identify countries not properly reporting catches to ICCAT		
Strengths	**Weaknesses**	
• ICCAT recognises the uncertainty of the estimates due to a) the application of average conversion factors that may not be precise, b) risks of double counting by applying	• A level of uncertainty (see strengths on the left); • Update required taking into account the new traceability	

conversing factors for products coming from the same fish, c) the likelihood that the SDP is not fully implemented by the importing countries and d) uses of highly aggregated data from the biannual reports which does not allow the validation of detailed data from the statistical documents	mechanism (catch documentation schemes)
Transferability of method to other situations? Ability to contribute to a global estimate?	
Yes, to estimate and compare with recent unreported catches in bluefin tuna by taking into account any change in the BFT catch documentation scheme.	

Study reference	Year published	Responsible organisation
Swartz and Ishimura (2014)	2014	UBC, Hokkaido University
Study Objective		
to create a baseline of total fisheries-related biomass removals in the Japanese Exclusive Economic Zones to supplement the reported commercial fisheries landings.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Japan	Commercial fishing in Japanese waters only (not distant water fleet), but including foreign fishing in Japanese waters, recreation.	1950-2010
Types of IUU activities considered by the study		
Unreported catches, including from the recreational fleet. Discards (not illegal). Illegal activities (gears; closures; abalone + cucumber by organised crime syndicates).		
Main methodology followed		
Catch reconstruction, which methodology has evolved from the anchor/influence approach, relying more on alternative information sources which may act as proxies of catch data (such as total consumption, exports, coastal community size) rather than the more difficult management based influence points approach originally.		
Data sources used		
• Landing statistics, recreational fisher surveys • Violations data related to illegal possession and sale of marine fish • Published estimates of discard rates.		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Illegal catches (including unreported), discarding by fleet, gear and fishery, with high quality levels. Separation of domestic/foreign and Japanese distant water fleets.		
Strengths	**Weaknesses**	
• Very detailed examination of sources, existing data.	• Historical back-extrapolations probably less reliable	
Transferability of method to other situations? Ability to contribute to a global estimate?		
Yes. As use in global estimate double counting would be avoided by clear separation of different contributions to the estimates and identification of different types of IUU.		

<table>
<tr><th>Study reference</th><th>Year published</th><th>Responsible organisation</th></tr>
<tr><td>Tesfamichael and Pitcher (2007)</td><td>2007</td><td>UBC, University of Asmara</td></tr>
<tr><th colspan="3">Study Objective</th></tr>
<tr><td colspan="3">Estimate of unreported catches of three major Eritrean red sea fisheries.</td></tr>
<tr><th>Geographical scope</th><th>Fishing activities included in the scope</th><th>Time period</th></tr>
<tr><td>Eritrea</td><td>Commercial shrimp, demersal finfish, pelagics</td><td>1950 - 2004</td></tr>
<tr><th colspan="3">Types of IUU activities considered by the study</th></tr>
<tr><td colspan="3">Unreported catch = misreporting in the small pelagic fishery, discarding in the demersal and shrimp fisheries. Illegal fishing not monitored (or expected).</td></tr>
<tr><th colspan="3">Main methodology followed</th></tr>
<tr><td colspan="3">Anchor and Influence (old method).</td></tr>
<tr><th colspan="3">Data sources used</th></tr>
<tr><td colspan="3">• Catch reporting (improved since 1993 independence)
• Observer monitored discard data
• Historical Studies of discarding</td></tr>
<tr><th colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</th></tr>
<tr><td colspan="3">Tabulation of influence factors and estimates of unreported catch. Use of influence factors more transparent than in some other studies of this type. Disaggregation by fleet allows calculation of discarding or underreporting.</td></tr>
<tr><th colspan="2">Strengths</th><th>Weaknesses</th></tr>
<tr><td colspan="2">• Detailed tabulation of results
• Major regime changes (independence; war) provide very sharp contrasts in the data</td><td>• Relatively few anchor points in centre of the series</td></tr>
<tr><th colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</th></tr>
<tr><td colspan="3">Yes.</td></tr>
</table>

<table>
<tr><td>Study reference</td><td>Year published</td><td>Responsible organisation</td></tr>
<tr><td>Varkey et al. (2010)</td><td>2010</td><td>UBC</td></tr>
<tr><td colspan="3">Study Objective</td></tr>
<tr><td colspan="3">Estimation of IUU in Raja Ambat, Eastern Indonesia.</td></tr>
<tr><td>Geographical scope</td><td>Fishing activities included in the scope</td><td>Time period</td></tr>
<tr><td>Raja Ambat Archipelago, 45,000 km2, NW of Papua, Eastern Indonesia</td><td>Small scale fisheries in reef and inshore areas (reef fish, tuna, anchovy, shark, sea cucumber, lobster)</td><td>Reconstructed catch for 1960 to 2006 to provide estimate of IUU catch in 2006</td></tr>
<tr><td colspan="3">Types of IUU activities considered by the study</td></tr>
<tr><td colspan="3">Reef fishery was divided into illegal catch using destructive fishing methods (e.g. blast fishing, cyanide) and unreported catch using other gears.
Due to difficulty of dividing up catches of other fisheries into elements of IUU, used on combined ‘unreported’ catch category to combine unreported artisanal and commercial fisheries.</td></tr>
<tr><td colspan="3">Main methodology followed</td></tr>
<tr><td colspan="3">Catch reconstruction, compilation of influence table, numerical influence total allocated to one of 5 categories of incentives for IUU, and incentive categories converted to actual catch estimates using anchor points to provide a range of IUU for each incentive category. Monte Carlo to estimate mean missing catch with error for each year.
IUU catch estimates converted to IUU catch revenues for 2003-2006.</td></tr>
<tr><td colspan="3">Data sources used</td></tr>
<tr><td colspan="3">• Catch records from Department of Fisheries
• Wide range of sources for historical events influencing IUU made mainly interviews with Nature Conservancy and local communities
• Anchor points – estimates of catch from literature and survey information
• Fish prices for survey data for 2006 and 2006 and CPI to convert nominal to real prices</td></tr>
<tr><td colspan="3">Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate</td></tr>
<tr><td colspan="3">Disaggregation by fishery for 6 fisheries for IUU catch and associated revenues</td></tr>
<tr><td colspan="2">Strengths</td><td>Weaknesses</td></tr>
<tr><td colspan="2">• Separation of illegal and unreported for reef fishery
• Inclusion of small-scale and commercial fishery
• Estimation of revenues associated with I and U estimates
• Community views incorporated into influence table</td><td>• Other fisheries just ‘unreported’
• Now statements at all in paper about any weaknesses in the analysis
• Prices missing for 2 of the 4 years in th revenue analysis
• Variable and large errors on the estimates of some of the fisheries covered
• Detailed influence table and basis for quantifying incentives for IUU not provided/transparent
• Anchor points not available for all incentive categories</td></tr>
<tr><td colspan="3">Transferability of method to other situations? Ability to contribute to a global estimate?</td></tr>
<tr><td colspan="3">Yes, but ability to contribute to global estimate low as for such a small area.</td></tr>
</table>

Study reference	Year published	Responsible organisation
Wagey et al. (2009)	2009	Research centre for capture fisheries, Agency for marine and fisheries research, Ministry of marine affairs and fisheries, Indonesia

Study Objective		
Providing estimates of IUU activities in Indonesian waters to develop management actions to combat illegal and non-reported fishing practices.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Arafura Sea (Arafura Sea Fisheries Management area including high seas)	Three industrial fisheries: fish trawling, shrimp trawling and bottom long line fishing	1976 -2005

Types of IUU activities considered by the study

Unreported catch consisting of (a) catches thrown away (by catch and discards), (b) catches not reported and misreported catches (reported but not recorded or improperly recorded) and (c) illegal fishing (definition of the authors).

Main methodology followed

Anchor points and influence table analysis with Monte Carlo estimation of confidence limits by qualitative and quantitative analysis. Influence factors consist of policy, rules, regulations, decisions and actions which can influence the rise or fall of IUU fishing activities; An anchor point consists of data and information regarding catch and fishing effort obtained as a result of research or from rules and regulations which can be used as a more reliable basis or reference point for estimation (Wagey et al., 2009)

Data sources used

- Data records from the (Indonesian) National Fisheries Statistics: landings and fishing efforts,
- Interviews: skippers, former skippers and crew, employees in harbours, fisheries public staff,
- Series of workshops to obtain additional data and validate the data obtained and the estimates, and
- Consultations

Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate

Type of estimates: base line catch = statistical data + (discards + misreported + illegal) with confidence limits (range) of the estimations; presented by five yearly percentages for each studied fishery; Conclusions: decreasing trend of illegal, misreported and discarded catch while Indonesian fisheries statistics shows an increase in fisheries catch; highest level of misreported catch occurs in the bottom long line fishery (95 %), highest level of illegal catch occurs in the fish trawl fishery (average 35 %) by transhipment, level of illegal catch unknown but assumed to be 5 % in the shrimp trawl and the bottom long line fisheries.

Strengths	Weaknesses
• Use of a statistical model to estimate a range of unreported and illegal fishing in the covered area • managing the fisheries resources in the Arafura Sea can succeed if these three industrial scale fisheries can be controlled: small-scale artisanal catches in the area are thought to be relatively	• The geographical coordinates of the Arafura sea area taken into account to estimate unreported and illegal fishing are not provided (a map with the covered area would have been very useful) • Use of Indonesian fisheries statistics only for the studied area (weakness if the covered area includes waters beyond

low on account of the small coastal population, (Nurhakim et al., 2009)	Indonesian waters – see bullet point above) • Focus on illegal fishing and unreported fishing (absence of mention of unregulated fishing) –authors explained their will to focus only on those two types of IUU fishing activities
Transferability of method to other situations? Ability to contribute to a global estimate?	
Transferability: yes, for estimating unreported catch. Ability to contribute: yes, but only in the covered time period and studied area (and after having a better understanding of the covered area)	

Study reference	Year published	Responsible organisation
Williamson et al. (2014)	2014	Australian Research Council Centre of Excellence for Coral Reef Studies
Study Objective		
Determine levels of illegal fishing in no-take Marine Reserves (NTMRs) on the Great barrier reef.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Great Barrier Reef, Queensland	Commercial and recreational fishing on coral reefs	2009
Types of IUU activities considered by the study		
Illegal fishing in no-take zones by commercial and recreational fishers.		
Main methodology followed		
Underwater surveys of discarded fishing line.		
Data sources used		
• Surveys lost gear inside and outside of NTMR • Estimates of accumulation rate		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Different accumulation rates inside and outside NTMRs allowed determination of different levels of fishing effort.		
Strengths	**Weaknesses**	
• Experimental, analytical • Does not rely on surveillance activity – survey based method • Indirect monitoring of IUU, dependent on accumulation rates of lost gear • Can generate an estimate of IUU activity in NTMRs • Can clearly identify one element of IUU, i.e. Illegal	• Intensive diving survey required • Only applicable where there are extensive known areas of reserves • Indirect estimate of IUU	
Transferability of method to other situations? Ability to contribute to a global estimate?		
May be useful where there are controlled areas such as MPAs; otherwise of limited contribution to global estimates. On the other hand, this is very clearly an Illegal activity.		

Study reference	Year published	Responsible organisation
Willock in OECD (2004) – section 'Compiling evidence' [to quantify IUU fishing] – chapter 5	2004	TRAFFIC International (international NGO monitoring wildlife trade)
Study Objective		
Presenting methods applied by TRAFFIC to identify and in some circumstance estimate IUU fishing by analysing trade data.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
Presenting methods with examples from different regions of the world, for instance: 1 CCAMLR area and high seas not under the mandate of an RFMO; 2. Global 3. Waters surrounding Ecuador's Galapagos Islands 4. South African waters	Example 1: Patagonian toothfish; Example 2: orange roughy; Example 3: sea cucumber *Isostichopus fuscus;* and Example 4: endemic abalone species *Haliotis midae*	Example 1: 2002 Example 2: 1977 – 2001 Example 3: 1998 – 2002 Example 4: in the late 90's
Types of IUU activities considered by the study		
IUU fishing especially illegal fishing and under-reported fishing.		
Main methodology followed		
• Comparing trade and catch data of a fish species (using live weight equivalence); • Identifying discrepancies of export and import figures from the exporting country and the importing country.		
Data sources used		
• Literature review; • Trade data compared against RFMO catch data and FAO catch data; • Market surveys (for a snapshot of trade and more detailed market surveys over a period of time to obtain a trend in assessing IUU fishing); and • Field research including consulting the industry		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Example 2: trade analysis confirming the likelihood of FAO underestimation of global catch of orange roughy (underestimation recognised by the FAO itself). The underestimate may be as high as 30 % in some years; Example 3: confirming illegal harvesting when the fishery was closed to commercial harvesting; Example 4: exports of abalone to China, the major importer of the south African endemic abalone, from countries not trading abalone from South Africa confirmed smuggling of abalone across borders. Other conclusions: RFMOs use trade information to identify countries engaged in trade of a certain commodities of a species where IUU fishing is an issue; example 1: lack of transparency of some of the world's largest importers (in this case in 2002, China); promoting transparency and use of the harmonised commodity system of trading (HS) to improve monitoring signs of illegal fishing through trade data.		

Strengths	Weaknesses
(presented by the author in the paper) • A complementary tool to quantify IUU fishing (strength presented by the author) • TRAFFIC aims to give conservative figures when estimating overall trade, then assessing IUU activities, as always inconsistencies occur in export, import and re-export data (discussed by the author in the paper)	(presented by the author in the paper) • Often difficult to access reliable information on domestic trade and consumption • Trade and market information cannot provide absolute results in terms of quantities of IUU fishing
Transferability of method to other situations? Ability to contribute to a global estimate?	
Answer to both questions: yes as a tool to quantify IUU fishing.	

Study reference	Year published	Responsible organisation
Worm et al. (2013)	2013	Dalhousie University and other Universities in the USA

Study Objective

Assessment of current status of shark populations including estimates of global catches, exploitation rates (catch divided by biomass) and potential extinction risks at current levels of exploitation. And from that discussion on management solutions.

Geographical scope	Fishing activities included in the scope	Time period
Global	Global shark fisheries	2000 and 2010

Types of IUU activities considered by the study

Unreported using other literature.

Main methodology followed

Generation of global catch and mortality estimates for sharks as a group based on reported catches and IUU catches, and discards based on observed discards and shark catch estimated from published sources by ocean basin and scaled up using longline effort.

Data sources used

- Average shark weights used to convert numbers to weights and vice versa
- Reported catches from FAO Fishstat (cross checked against UBC Seas Around Us Project database, and also for fins from trade data in Fishstat (compared for regional comparison with Hong Kong government trade data)
- IUU catch estimated using Agnew et al 2009 and global catches
- Published observer data for discards

Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate

Global figure of IUU shark catches (not disaggregated by I, U and U, area, shark species, or fishing metier).

Strengths	Weaknesses
• Conservative estimate of IUU as assumed that sharks represent same proportion in reported catch as in unreported catch (unlikely to be the case) • Rationale for various assumptions clearly stated	• Big range in total possible values of shark mortality (63-273 million/year) • Many assumptions in the various steps • IUU part of global shark catch based on application of Agnew et al (2009) estimate of IUU catch in total global catch, to recorded shark catches • Failure to consider what proportion of 'finned' mortality is also illegal based on finning regulations

Transferability of method to other situations? Ability to contribute to a global estimate?

Not really an assessment of IUU accept to the extent that global rates of IUU (as reported in Agnew et al, 2009) are applied to total catch based on assumption that sharks represent same proportion in reported catch as in unreported catch. Focus of paper is on estimating global catch and mortality.

Study reference	Year published	Responsible organisation
Zeller et al. (2011)	2011	Seas Around Us Project / UBC
Study Objective		
To estimate total removals (landings plus unreported landings, plus discards plus recreational removals) in 9 Baltic Sea countries.		
Geographical scope	**Fishing activities included in the scope**	**Time period**
9 Baltic Sea countries 397,000 km2	Cod, herring, sprat, flatfish, salmon, others, in Baltic	1950 to 2007, and 2000 to 2007
Types of IUU activities considered by the study		
Unreported commercial landings (illegal), discards (unreported) and recreational removals (unregulated).		
Main methodology followed		
Bottom up approach to reconstruct catch time series to provide total removals. Unreported landings for cod and salmon converted to %s of Baltic-wide reported landings to form anchor points. Discards differentiated into types and % estimated from literature. Methodology for recreation removals not clearly explained.		
Data sources used		
• National data, published and grey lit, media sources, communication with fisheries expert from the region • ICES catch statistics database (reported landings by country, species, area, and year) • ICES stock assessment results database (data used by working groups in stock assessments on selected species) • ICES stock assessment working group reports		
Types of estimates / conclusions produced (incl. disaggregation levels) and quality of quantitative estimate		
Total removals 30-35% higher than reported landings (unreported landings 14%, discards 9%, recreational fisheries 3%, data source adjustments 3%). Difference between removals and reported landings also provided by species and country and type of additional removals.		
Strengths	**Weaknesses**	
• Differentiation of types of discards (underwater due to gear selectivity, ghost fishing, high-grading, and seal-damaged discards) • Covers recreational fishing, and some elements of all I, U, and U	• Poor explanation of some aspects of building up removal estimates (e.g. for recreational fisheries) • Unreported catches not available from working group reports for many species	
Transferability of method to other situations? Ability to contribute to a global estimate?		
Yes potentially, but would rely on there being similar data sources would be available to build up total removal estimates (e.g. stock assessment working group estimates of unreported catches, good data on different types of discards, and surveys of recreational fishing).		