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Framework for giving advice on minimum size limits

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Summary (English):

Establishing a minimum size limit, the length at which fish change from "unwanted bycatch" to "desired catch", is a useful management tool to avoid growth and recruitment overfishing and improve sustainable yield. We review and recommend methods for giving advice on how to set minimum size limits across a range of data and model complexity. The simplest methods are based on maturity or growth data and can be used for data-limited stocks without assessments. More complex methods are recommended for stocks with age-based assessment models. We also provide comments on practicality, caveats, and examples.

Summary (Norwegian):

Å etablere et minstemål, lengden der fisk endrer klassifisering fra "uønsket bifangst" til "ønsket fangst", er et nyttig forvaltningstiltak for å unngå vekst- og rekrutteringsoverfiske og forbedre bærekraftig høsting. Vi gjennomgår og anbefaler metoder for å gi råd om hvordan man kan sette et minstemål på tvers av et spekter av data og modellkompleksitet. De enkleste metodene er basert på modnings- eller vekstdata og kan brukes for databegrensede bestander uten vurderinger. Mer komplekse metoder anbefales for bestander med aldersbaserte vurderingsmodeller. Vi gir videre kommentarer om praktisk anvendelse, forbehold og eksempler.

Content

1 - Introduksjon

1.1 - Definisjon

«Biologisk minstemål» velger Havforskningsinstituttet å definere som den lengden hvor en fisk endrer klassifisering fra «uønsket bifangst» til «ønsket fangst» basert på en målsetting om å unngå vekstoverfiske, men også å unngå rekrutteringsoverfiske.

1.2 - Bakgrunn

Vekstoverfiske er definert som høsting av fisk som ikke har utnyttet sitt vekstpotensiale. For en årsklasse av fisk tilsvarer det at det fiskes mens biomassen av årsklassen fortsatt er i vekst. Når veksten går ned ved høyere alder vil den etter hvert ikke kunne kompensere for naturlig dødelighet. Individvekst går betydelig ned når fisken blir moden og danningen av gonader begynner. Energi fra beiting som tidligere ble omdannet til vekst blir nå kanalisert til danning av gonader. Årsklassens biomassevekst vil typisk stoppe opp når en tilstrekkelig andel av årsklassen er modne. Når dette skjer i er også arts- og bestandsavhengig. For torskefisk kan det se ut som at modning er tettere knyttet til lengde enn til alder.

Rekrutteringsoverfiske er et fiskepress som er så høyt at gytebestanden blir svekket til nivå hvor rekrutteringen er redusert. Ved å la være å fiske umoden fisk vil dette føre til langt større gytebestand og på den måten kan man også unngå rekrutteringsoverfiske.

Et minstemål kan beregnes ut ifra vekstbetraktninger og utbytte per rekrutt eller basert på modningskurver (andel modne ved lengde). Det kan argumenteres at det høyeste av disse to kandidatene til minstemål bør velges. Vi må i tillegg påpeke at hvis for en bestand et minstemål basert på modning er det høyeste, kan man likevel opprettholde tilstrekkelig gytebiomasse ved å redusere fiskepresset tilstrekkelig. Vanligvis vil de to kandidatene til minstemål være nokså like siden lengdevekst avtar når fisken blir moden.

1.3 - Bruk av minstemål i anvendt fiskeriforvaltning

Langtidsutbyttet til en fiskeressurs avhenger av både fiskepress og beskatningsmønster. Fiskepress vil vanligvis reguleres ved at man benytter en totalkvote, men det er også mulig å begrense fiskepress ved å regulere innsatsen i fiskeriene. Innsats kan reguleres gjennom antall fartøy og størrelsen på disse, men langt vanligere er stenging av sesong eller område.

Beskatningsmønster påvirkes av teknisk utforming av redskap (maskevidde, krokstørrelse etc) og ikke minst påvirkes beskatningsmønsteret av hvor og når det fiskes. I et blandingsfiske vil det være et behov for avveininger siden minstemål og beskatningsmønster vanskelig kan optimaliseres for alle arter som fiskes. Men det må på det sterkeste påpekes at fisk vokser også etter første gangs gyting og at reduksjon i langtidsutbytte ved å vente med uttak vil være betydelig lavere enn å fiske fisk som ikke har utnyttet sitt vekstpotensiale.

Minstemål er i seg selv et noe uklart begrep og på engelsk brukes også uttrykket «minimum landing size». De negative følgene i form av betydelige utkast er velkjente. I Norge har fokus vært på å gjennomføre fiskeriene på en måte som gjør at man unngår å fiske fisk under minstemålet. Vesentlig innsats har blitt gjort for å utvikle redskap med hensiktsmessig seleksjonsegenskaper og i tillegg ble det innført regelverk om stenging a fiskefelt basert på prosentvis innblanding av undermåls fisk samt et regelverk som omhandler fiskerens eget ansvar for varsomhet og flytting av fiskeriaktivitet hvis det ikke lar seg gjennomføre uten for stor innblanding av undermåls fisk.

Gullestad et al. (2014; 2015) gir utmerkede beskrivelser av utviklingen av norsk fiskeriforvaltning de siste 50 årene og de store økonomiske og økologiske bærekraftgevinstene som kan oppnås gjennom innsats for å forbedre beskatningsmønsteret. Nøkkeltiltak har vært innføringen av områdestenging i sanntid (1984), forbud mot utkast av torsk og hyse (1987), samt sorteringsrist i reke-trål (1991) og bunnfisk-trål (1997).

1.4 - Rådgiving

ICES har for tiden ingen retningslinjer for beregninger av og utforming av råd om minstemål. Lengden av fisk og avledede størrelser og betraktning blir likevel benyttet i noen metoder for bestandsberegning. Dette er gjerne for mer data fattige bestander som benytter lengdebaserte indekser/indikatorer. Eksisterende rammeverk i ICES omhandler flere aspekter av rådgiving for en lang rekke situasjoner, men omhandler ikke rådgiving om hvordan minstemål kan benyttes i forvaltning. Siden det ikke finnes noe standardisert rammeverk for anbefalinger om minstemål, gis det heller ikke eksplisitte råd om minstemål og bruk av minstemål.

Dagens kvoterådgiving baserer seg på målsettinger som omhandler langtidsutbytte fra en bestand. Kvoteanbefalingen tilsvarer vanligvis tilhørende referansepunkt F_{MSY}. Langtidsutbytte og F_{MSY} er ikke uavhengige av beskatningsmønsteret (seleksjonsmønsteret). Tidligere og ikke minst før innføringen av kvotebegrensninger i fiskeriene hadde ICES sin rådgiving betydelig fokus på rådgiving relatert til å unngå vekstoverfiske.

1.5 - Praktiske problemer (av noen omtalt som utfordringer)

Fritidsfiske: Det er generelt lite kunnskap om minstemål blant fritidsfiskere, mens det er noe bedre når man snakker med gjester på turistfiskebedrifter (Ferter et al. 2023). Håndheving av minstemål når det brukes redskap med «dårlige» seksjonsegenskaper er et betydelig problem særlig relatert til overlevelse av fisk som gjenutsettes.

Kommersielt fiske: Utforming av redskap i kombinasjon med område og sesongreguleringer for å oppnå et ønsket beskatningsmønster er vanskelig. Man må i svært stor grad unngå å fiske fisk under minstemålet for å unngå at minstemål blir et insentiv til omfattende og ødeleggende utkast. De praktiske problemene i den forbindelse inkluderer dødelighet hos fisk som blir selektert ut. Vi nevner spesielt sild, makrell og hyse (Ingolfsson et al. 2007). I tillegg kan blandingsfiske utgjøre utfordringer for arts-spesifikke anbefalinger, og det kan hende at det ikke er mulig å optimalisere selektiviteten for alle arter. Utvalget av mulige avveininger bør vurderes.

2 - Framework

The methods in Table 1 could support advice on minimum size limits, L_{min}. Additional background and reasoning is in the following sections.

Table 1. Methods to support advice on minimum size limits, L_{min}. The two left columns protect against growth (yield) vs. recruitment (reproductive) overfishing. L_{min} should be at least as large as the "protect reproduction" value. For commercially important species, the higher of the two values should be used to protect against both forms of overfishing. In practice, the two values may be similar because fish growth generally slows at maturation. Approaches increase in complexity going down rows of the table. For a given stock the highest realism feasible should be used.

	Protect reproduction	Protect yield	Data/effort required	Reference
Data-limited	**1.1-1.2 * L_{50}** or **0.56 * L_∞**		Length + maturity data to estimate L_{50}, or length + age data to estimate L_∞. Need a wide range of length/age (i.e. immature fish), so likely need survey data	Prince and Hordyk (2018) Froese et al. (2016) Fall et al. (2022, 2023, 2024) Stock et al. (2025)
Per-recruit analysis (stock-specific)	**Spawning Potential Ratio (SPR), spawning biomass per recruit (SSBPR)** from a range of F and selectivity. Include uncertainty in life history parameters.	**Yield-per-recruit (YPR)** from a range of F and selectivity. Include uncertainty in life history parameters.	Length-based SPR simulations need only life history parameters. SSBPR and YPR need survey biological data (length, age, weight, maturity). Can also use age-based model if available.	Hordyk et al. (2015, 2016) Froese et al. (2016) Skjæraasen et al. (2021)
Full life cycle	**Yield** as a function of F and selectivity, accounting for reduced recruitment at low stock size.		Age-based model (with S-R) or data-limited model + assumptions about S-R.	
Age-based MSE	**MSE simulations using age-structured model** to include recruitment variability. Metrics: average yield, probability SSB > B_{lim}.		Age-based model and simulations	
Age- and length-based	**Yield from an age-length structured model**. Includes the full life cycle and effect of catching faster-growing fish in a cohort first. **L_{min}** directly affects selectivity-at-length.		Age-length model	Kvamme and Bogstad (2007)
Age- and length-based MSE	**MSE using age-length structured model**. As above but can include variability of recruitment, growth, or other processes and estimate probability-based metrics like prob(SSB > B_{lim}).		Age-length model and simulations	

L_{50}: length at 50% maturity, SSB: spawning stock biomass, B_{lim}: biomass limit reference point, S-R: stock-recruitment relationship

2.1 - Comments

We believe that "minstemål" should be used as a general criterion for improving size selectivity patterns or for closing areas with large catch of undersized fish. Gullestad et al. (2014; 2015) provide excellent descriptions of how Norwegian fisheries management evolved over the last 50 years and the large economic and ecological sustainability gains that can be achieved from efforts to improve exploitation patterns. Key actions have been the introduction of real-time area closures (1984), discard ban for cod and haddock (1987), and sorting grids in shrimp trawl (1991) and groundfish trawl (1997) fisheries.

The **precautionary approach to fisheries** "recognizes that changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to changing environment and human values." It takes into account "uncertainties in fisheries systems and the need to take action with incomplete knowledge" (FAO 1996). Particularly relevant to minstemål advice for data-limited stocks is that **priority should be given to conserving the productive capacity of the resource** where the likely impact of resource use is uncertain. The precautionary approach was incorporated into official Norwegian fisheries policy in 1997 (Gullestad et al. 2014).

Ideally, information on both yield per recruit and maturation should be used in deciding on a minimum size regulation. Simulations of long-term yield that consider the stock-recruitment relationship and recruitment variability are the most comprehensive, but also take the most resources. Different levels of complexity are possible given the importance of a stock, likely value to be gained by implementing a minimum size, and availability of data, existing model and MSE code, and resources.

We note that a yield-per-recruit (YPR) analysis which does not include recruitment (full life cycle) could produce L_{min} advice that is too low and potentially be dangerous for the stock. Consequently, any **L_{min} advice based on YPR should be bounded by a maturity-based analysis** .

2.2 - Caveats

- The minimum information to provide L_{min} advice is an estimate of the length at 50% maturity, L_{50}, or maximum length from a von Bertalanffy growth curve, L_∞. This **generally requires survey data** because fisheries typically do not catch enough young, immature fish. Without an estimate of L_{50} or L_∞ we would not be able to give advice at all.
- **Mixed fisheries** (blandingsfiske) may pose challenges to species-specific recommendations, and it may not be possible to optimize selectivity for all species. The range of possible tradeoffs should be considered.
- **Low awareness of the minimum size among recreational fishers** (fritidsfiskere) will reduce its effect. This is especially a problem among Norwegian residents, they have much lower awareness than tourists fishing from registered businesses. Estimates from Troms: 9%, Hordaland: 18%, Oslofjord: 16% (Ferter et al. 2023; Kleiven et al. in prep).
- Higher minimum size limits may result in lost yield and higher **mortality from discards/release**. Gear regulations to avoid catch of fish below the minimum size should be considered, as well as survival rates of released/discarded fish below the minimum size.

2.3 - Data-limited stocks: **1.1-1.2 * L_{50}**

“Fish should be allowed to spawn (at least) once” is a well-founded principle (Myers and Mertz, 1998; MacCall, 2012). Several have shown that the optimal catch length occurs when cohort biomass is maximized, which is generally near maturation because that is when growth slows (energy goes increasingly to reproduction) and mortality reduces cohort biomass (Beverton and Holt, 1957; Froese and Binohlan, 2000). It is generally optimal to fish stocks with higher natural mortality (M) at younger ages.

The recommendation of setting L_{min} = 1.1-1.2 * L_{50} is from Prince and Hordyk (2018), based on age-length based simulations across life history strategies (M/k). They show that yields are optimized across a wide range of F, including very high F, if L_{min} is set above L_{50}. They show that this also preserves a minimum level of spawning potential to reduce the chance of recruitment overfishing and population collapse.

The goal is 'sustainable pretty good yield' in fisheries without good age or catch data or the ability to control F. This is appropriate for coastal stocks, e.g. coastal cod, where we don't know recreational catch and can't control F with a quota. This was the rationale behind our advice to increase the cod minstemål from 44 to 55 cm north of 62°N inside the 4 nm limit where most of the coastal cod is taken.

The approach **could be broadly applied across other data-limited stocks**, as it only requires sufficient length and maturity data to estimate L_{50}. It is especially applicable to coastal stocks where recreational fishing is important relative to commercial fishing. We could summarize L_{50} and recommended L_{min} for many stocks together with other groups.

Example HI advice

- Coastal cod north of 62°N, advised L_{min} increase from 44 cm to 61-67 cm (Fall *et al.*, 2022, 2023, 2024).
- Coastal cod south of 62°N, advised L_{min} increase from 40 cm to 55 cm for Vestlandet and 45-50 cm for Skagerrak (Stock *et al.*, 2025).

Caveats and feasibility

- To estimate L_{50} with reasonable precision, data on immature fish are needed. Surveys are the best source; few immature fish are available from landing sites or the reference fleet.

2.4 - Data-limited stocks: **0.56 * L_∞**

An alternative data-limited recommendation of L_{min} = 0.56 * L_∞ is from Froese *et al.* (2016), based on setting the mean length in the catch to the length where the biomass of an unexploited cohort is maximized, L_{opt}. The connection to the previous, maturity (L_{50})-based approach is that under the (often reasonable) assumptions that fecundity is proportional to body weight and fish mature at the peak of cohort biomass, then the peak of cohort fecundity coincides with the peak of cohort biomass.

The recommended L_{min} = 0.56 * L_∞ is a simplification of Equation 1 in Froese et al. (2016) under the assumption that M/k = 1.5 and F/M = 1. This is a good starting point for data-limited situations but may not be appropriate for all stocks. Different levels of sophistication, i.e. using stock-specific estimates of F/M or M/k, can be used to calculate L_{min} using the full equation:

$$L_{min} = \frac{L_\infty(2 + 3F/M)}{(1 + F/M)(3 + M/k)}$$

Alternative methods can be used to estimate F/M for a given stock, such as 1) catch length distributions or 2) F/F_{MSY} estimated by a surplus production model (e.g. SPiCT, as for coastal cod 62-67N). An advantage to this is that sustainable F and L_{min} are connected: if F is high, then L_{min} must also be higher, whereas a low L_{min} can be used if F is low. For the example of coastal cod 62-67N, the current estimate of F/F_{MSY} is 1.8, which implies that L_{min} should be higher, 0.59 * L_∞ instead of 0.56 * L_∞.

Species' life history can differ substantially from the 'invariant' M/k = 1.5, and better knowledge should be used if available. As an example, recent estimates for Northern Shelf anglerfish are M = 0.36 and k = 0.06, which gives

M/k = 6 (ICES, 2024). Using M/k = 6 instead of M/k = 1.5 gives $L_{min} = 0.28 * L_\infty$.

2.5 - Data-limited stocks: estimation of L_{50} and L_∞

Good estimates of life history parameters, such as L_{50} and L_∞, are also important in other data-limited fisheries management methods, such as the LBSPR model and ICES rfb rule for category 3 stocks (Hordyk *et al.*, 2016; ICES, 2022). Some best practices for estimating L_{50} and L_∞:

- For data-limited minstemål advice*, use parameters that give a more precautionary (higher)* L_{min}. One example is if growth or maturity have *changed over time*, which can be due to many possible factors that are difficult to unravel even in data-rich situations (e.g. stock density, fishery-induced evolution, ecological interactions, or climate change). Another example is species which have strong *sexual dimorphism*, in which case we advise estimating L_{50} and L_∞ for each sex and using the larger values.
- Use weights when fitting the von Bertalanffy growth curve to correct for common biases. It is easy to combine multiple weights by multiplying them together.
  - Selectivity is typically driven by length more than age, which means that larger fish of each age are more likely to be sampled (especially for younger ages in the fishery). Selectivity parameters can be estimated using length-distribution data and the LBSPR model (Hordyk *et al.* , 2016), and then used to calculate weights (Taylor et al., 2005; ICES, 2021). This can be especially important when combining data from multiple sources with different selectivities.
  - Length stratification in survey sampling (e.g. sample otoliths from 5 fish per length group). Weights can be calculated following Perreault *et al.* (2020).
  - Estimating growth or maturity curves is difficult when there are few data from young or old fish; when most data are from middle-aged fish the length-age relationship can be nearly linear and L_∞ over-estimated. Consider a method to 'help bend the curve':
    - Weight data by $1/n_a$, where n_a is the number of fish of age a. This gives equal weight to all ages and will upweight datapoints from ages with few observations, e.g. Northern Shelf anglerfish (ICES, 2024).
    - Fix t_0 or use a penalty/prior.
    - Add artificial small/young fish drawn from a reasonable distribution, as in 'force.zero.group' in the 'ggFishPlots' R package (Vihtakari, 2024).
- Uncertainty in L_{50} and L_∞ should be reported using appropriate confidence intervals, e.g. from bootstrapping. This uncertainty is easy to propagate to minstemål advice by calculating L_{min} for the L_{50} and L_∞ confidence interval limits.

We intend to provide functions for estimating growth and maturity following these methods in the 'ggFishPlots' R package (Vihtakari, 2024). Standardized and well-documented code will make these methods easier to implement and improve life history parameter estimates across HI.

2.6 - Per-recruit analysis (stock-specific)

Per-recruit analyses could also be widely applied to specific stocks, using only survey data for data-limited stocks or age-based models for stocks where they already exist. Per-recruit analyses give separate values to protect against reproductive vs. yield overfishing.

Caveats

- If using an age-based model, note that there is often a big difference between weight-at-age in fishery catch vs. the stock/population, which is an effect of the fishery selecting fish based on size and not age. If the fishery catches lots of big/young (fast growing) fish this can make a difference on the cohort biomass by age and therefore your inference on what an optimal L_{min} would be, e.g. NEA haddock. In such a case, using weight-at-age in the catch would give advice to set L_{min} too low. We advise using weight-at-age in the population/stock.

Example HI advice

- Pollock north of 62°N (no assessment model), advised L_{min} = 50 cm (Skjæraasen *et al.*, 2021).

2.7 - Full life cycle

For the bigger stocks with more data and age-based assessment models (e.g. SAM), it would be better and relatively simple to calculate yield as a function of F and selectivity. Calculating yield instead of yield-per-recruit accounts for reduced recruitment at low stock size, and this is simple to do for stocks with an age-based model including a stock-recruitment relationship (e.g. not for kysttorsk nord). The approach could also be done using a data-limited (length-based) model and assumptions about the stock-recruitment relationship, or e.g. random draws from a distribution of possible steepness values.

Caveats

- Same caveat as above: use stock weight-at-age, not catch weight-at-age.

2.8 - Age-based MSE

The next step in complexity for stocks with an age-based model (e.g. SAM) would be MSE simulations that could additionally include variability in life history (recruitment, growth, maturity) and estimate the performance of a minimum size limit using metrics like average yield, probability of yield over a target, and probability of maintaining SSB over biomass reference points like B_{lim}.

2.9 - Age- and length-based

For the most valuable stocks, e.g. skrei, it could be worth developing length- and age-structured models to most accurately estimate the effect of changing the minimum size limit (or selectivity length pattern more generally) on age-structured population dynamics. Gadget is an age- and length-based model framework which could be used, and some HI researchers are familiar with.

Example HI advice

- Kvamme and Bogstad (2007) developed an age- and length-based model for NEA cod, and it is worth updating and using for advice as the yield could likely be substantially increased. They suggested that delaying harvest until 8-11 years old, ca. 80-95 cm, would increase YPR by 15-20%.

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