Pyrenean Desman and high-head hydroelectric intakes

Critical analysis of existing prescriptions and proposal of a proportionate dual protection criterion

Author	M. Denis Bouzon
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ABSTRACT:
The Pyrenean Desman (Galemys pyrenaicus), a species protected under Habitats Directive 92/43/EEC, represents a major regulatory challenge for hydraulic projects in the Pyrenean zone. LIFE+ Desman Booklet 4 (Lim et al., 2020) recommends a screen gap below 15 mm for intakes, citing a risk of the animal falling into the water chamber, without distinction of structure type or aspiration velocity.

This note demonstrates that this fall risk is physically non-existent for high-head plants fitted with a settling basin. It further demonstrates that the 15 mm gap, without control of aspiration velocity, causes rapid clogging of the screen — creating a fatal impingement risk for juveniles, whose swimming capacity is lowest.

The note proposes an inseparable dual criterion: aspiration velocity below 35 cm/s — a precautionary threshold derived from the preferred current velocity of adult Desmanids (> 70 cm/s, Biffi et al., 2017) — and a protective bar spacing of at least 20 mm. A verifiable calculation method is provided for Water Act authorisation files.

Keywords: Pyrenean Desman, desman-life.fr, DREAL, DDT, CEN Aquitaine, PNP, intake, hydroelectricity, forebay, 15 mm screen gap, clogging, gap, juveniles, Water Act, proportionality, Habitats Directive 92/43/EEC.

1. Introduction

The Pyrenean Desman (Galemys pyrenaicus) is a small semi-aquatic mammal endemic to the Pyrenean massif and the north-western quarter of the Iberian Peninsula. Listed in Annexes II and IV of Habitats Directive 92/43/EEC, it benefits from strict protection under French law and constitutes a major regulatory challenge for any hydraulic development project in the Pyrenean zone.

Since 2009, two successive National Action Plans (PNA) and the European LIFE+ Desman programme (2014-2020), coordinated by the Conservatoire d'Espaces Naturels de Midi-Pyrénées (CEN MP), have produced methodological tools for instructing services and engineering consultancies, including four reference technical booklets (CEN MP, 2017-2020).

However, the National Nature Conservation Council (CNPN), in its December 2019 opinion, explicitly identified the need to "provide guidance to developers on habitat management and on elements essential for species maintenance, such as minimum flow rates necessary for species survival (as one example)".

This recommendation remains without an operational response in the specific context of small high-head hydroelectricity, for which existing tools contain fundamental technical inaccuracies analysed in this note.

Source:

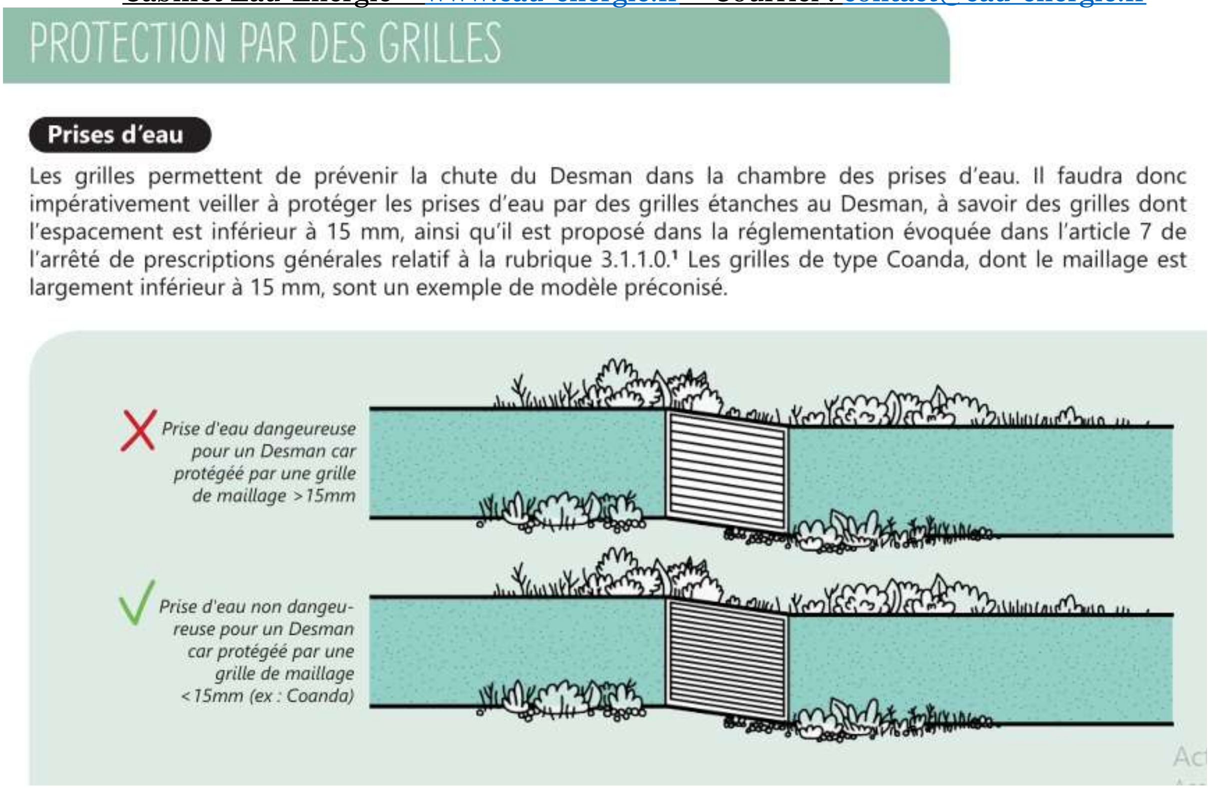
"CNPN opinion following evaluation of the 1st PNAD (2019) — PDF"

http://www.desman-life.fr/sites/default/files/COMMISSION%20%20ECB%20%20DU%20%20CNPN%20%20du%20%2019%20%20D%C3%A9cembre%20%202019.pdf

1.1. Current LIFE recommendation for intakes

The prescriptions of LIFE+ Desman Booklet 4 (Lim et al., 2020) relating to intakes do not distinguish between different types of hydraulic structures. Booklet 4: Technical guidance, page 39/45, states as a recommendation for intakes:

> *"Screens prevent the Desman from falling into the water chamber of intakes. It is therefore essential to protect intakes with Desman-proof screens, i.e. screens with a gap below 15 mm, as proposed in the regulations referred to in Article 7 of the ministerial order of general prescriptions relating to rubric 3.1.1.0. Coanda-type screens, whose mesh is well below 15 mm, are an example of a recommended model."*



PROTECTION PAR DES GRILLES

Prises d'eau

Les grilles permettent de prévenir la chute du Desman dans la chambre des prises d'eau. Il faudra donc impérativement veiller à protéger les prises d'eau par des grilles étanches au Desman, à savoir des grilles dont l'espacement est inférieur à 15 mm, ainsi qu'il est proposé dans la réglementation évoquée dans l'article 7 de l'arrêté de prescriptions générales relatif à la rubrique 3.1.1.0.[1] Les grilles de type Coanda, dont le maillage est largement inférieur à 15 mm, sont un exemple de modèle préconisé.

Source:

https://www.desman-life.fr/sites/default/files/Livret%204%20-%20Guide%20technique%20VF%20%28pages%20simples%29.pdf

Firstly, the article of the ministerial order mentioning the possibility of adapting prescriptions to intakes with a gap from 20 mm to 15 mm is the ministerial order of 15 September 2015, Article 10, not Article 7.

Source:
https://www.legifrance.gouv.fr/loda/id/JORFTEXT000031223404

The LIFE document describes a risk of the Desman "falling" into the water chambers of a hydroelectric plant intake in the Pyrenees.

However, this description of a fall risk does not correspond to the mechanical and hydraulic reality of a high-head hydroelectric intake in the Pyrenees. We therefore describe below a typical intake and identify the actual risk zones.

2. Technical description of a high-head hydroelectric intake

High-head plant intakes in the Pyrenean environment invariably consist of the following elements:

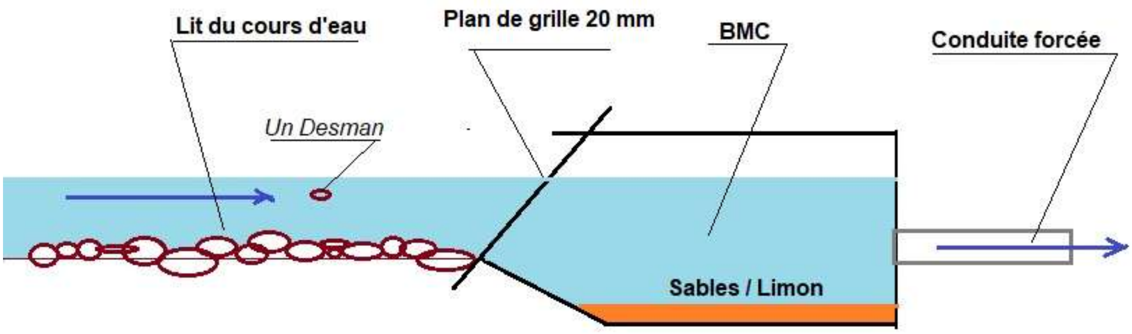
2.1. General architecture

Forebay: Water captured is conveyed into a basin deeper than the watercourse to reduce velocity and allow gravity settlement of suspended matter (sand, silt, fine gravel). The primary objective is to protect the turbine against abrasion from material possibly drawn into the penstock.

Screen surface: The inlet of a forebay is protected by a screen, which has a triple function: firstly to prevent intrusion by persons; secondly to prevent entry of pebbles and stones that could fill the forebay; thirdly to prevent intrusion of any fauna into the forebay, with a fatal suction risk into the penstock.

De-sanding valve: Forebays are ideally equipped with a bottom de-sanding valve, designed to flush sands and silts downstream after they have settled in the forebay.

Cross-sectional diagram:



Absence of hydraulic head difference at the screen surface

> Unlike the recommendations of LIFE+ Desman Booklet 4 (Lim et al., 2020), there is no head loss at the screen surface, or this is at least negligible (Δh ≈ 0). There is no constitutive level difference causing a "fall" between the upstream and downstream sides of the screen surface. The "fall" risk described by Lim et al. (2020) is not relevant for hydroelectric plant intakes, and is physically non-existent for submerged high-head intakes.

3. Critical analysis of the 15 mm screen gap recommendation

LIFE+ Desman Booklet 4 (Lim et al., 2020) recommends installing a screen with a bar spacing — called the gap — below 15 mm. This recommendation aims to prevent the Desman from entering the penstock. It is based on a legitimate objective. However, it does not account for two essential field realities: the natural behaviour of the Desman, and the nature of the sediments transported by Pyrenean torrents.

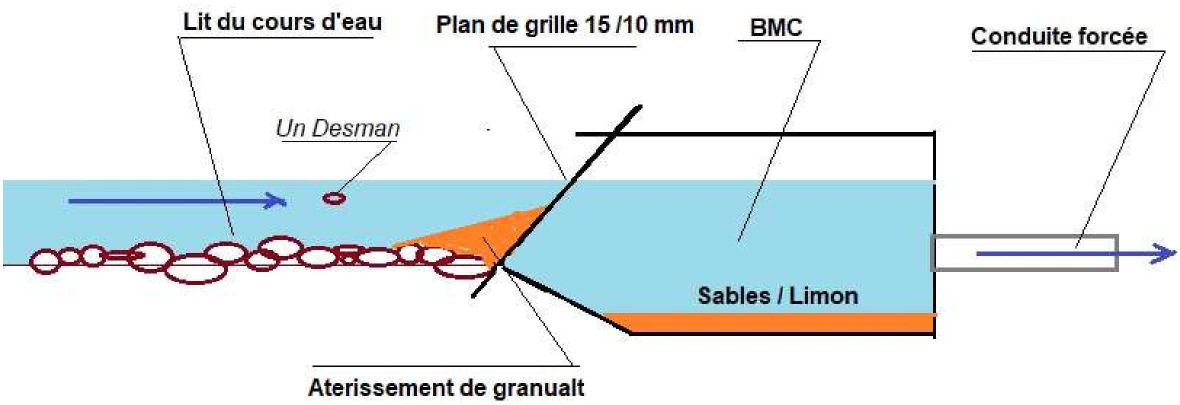
The Pyrenean Desman is a semi-aquatic animal that lives along riverbanks and swims mid-water to feed. Its protection does not rest on the screen gap, but on the velocity at which water is drawn in: if this velocity is below its swimming speed, the animal naturally moves away from the screen, without effort or danger.

3.1. Risk No. 1 — Inevitable clogging of a 15 mm screen in a Pyrenean torrent

To understand why a 15 mm gap screen is ill-suited to Pyrenean high-head plants, one must understand the nature of the materials transported by these torrents.

Pyrenean mountain watercourses permanently carry sediments of variable size: coarse sands, gravels, and pebbles, whose grain size ranges from a few millimetres to several centimetres. The higher upstream towards high-altitude sources, the coarser these materials become.

Intakes of high-head plants are designed precisely to allow natural transit of these sediments: water passes into a settling basin where the heaviest materials settle, and fine sands pass through the screen to be evacuated by the de-gritting valve.



Explanatory diagram

A 15 mm gap screen blocks aggregates larger than 15 mm — which corresponds precisely to the coarse sands and small gravels naturally present in these mountain torrents. These materials, instead of passing through the screen and being evacuated normally, accumulate in front of and within the screen. This is what is called clogging.

When the screen clogs, the available surface for water passage progressively decreases. Yet the captured flow remains constant. The consequence is mechanical and inevitable: the same volume of water must pass through an ever-smaller surface, which accelerates the aspiration velocity in the still-open zones.

> In simple terms: **the more the screen clogs, the harder the water pulls in the unblocked zones.**

Clogging, inevitable under normal operation, thus progressively transforms the screen into a trap for the Desman — and in particular for its juveniles, whose swimming capacity is lowest.

3.2. Counter-productive effect — clogging transforms the screen into a trap

Aggregates retained by the fine-gap screen accumulate at its base and progressively clog the filtering surface. The effective screen area decreases, and the aspiration velocity mechanically increases in the remaining open zones.

A clogging of only 30% of the surface — a common value under normal operation — is sufficient to raise the aspiration velocity from 44 cm/s to 63 cm/s in the numerical example presented in section 4.3. This velocity exceeds the maximum swimming capacity of juvenile Desmanids, i.e. the critical threshold of 35 cm/s established in section 3.3. These individuals are impinged against the screen and can no longer escape.

> **The 15 mm screen prescribed to protect the species thus becomes a fatal trap — *exactly the opposite effect to the intended protection objective.***

> **Clogging mechanism:**
>
> - A screen with a 15 mm or smaller gap obstructs the aggregates of mountain watercourses.
> - The accumulation of these aggregates in front of the screen adds to the clogging.
> - The reduction of the wetted screen surface at constant flow causes acceleration of the aspiration velocity at the screen, in still-open zones.
> - When the screen velocity exceeds the Desman's swimming capacity, any individual approaching within 10/15 mm of the screen finds itself stuck, unable to swim against the current.
>
> **Conclusion: The 15 mm screen prescribed to protect the Desman transforms into a fatal impingement trap — exactly the opposite effect.**

To prevent any impingement risk, the determining criterion is the aspiration velocity at the screen surface, which must be kept below the critical threshold of 35 cm/s established in section 3.3.

3.3. Swimming velocity of the Desman

The LIFE+ Desman programme (2020) documents that the species preferentially selects zones with currents above 70 cm/s for its hunting activities (Biffi et al., 2017; LIFE+ Desman, 2020). This data implies that the adult Desman is capable of maintaining itself in currents of at least 70 cm/s under sustained effort. Furthermore, Lim et al. (2021) document active movements of more than 6 km in less than three days on the Vicdessos (Ariège), confirming a locomotor capacity in torrential environments significantly above the aspiration velocities retained in this note.

Applying the precautionary principle, and in line with good practice for dimensioning fish protection structures, one can postulate that juveniles are capable of swimming at half the adult velocity, i.e. at 35 cm/s.

Below this threshold, the Desman perceives the current but can freely move away from it without effort. It can travel normally along the watercourse, pass in front of the intake, and return to the bank without any danger.

Methodological note:
In the absence of published data on the swimming velocity of juvenile Desmanids, and in accordance with the precautionary principle defined in Article L.110-1 of the Environmental Code, we retain 35 cm/s as the critical threshold — half the current velocity documented for adults during hunting (> 70 cm/s, Biffi et al., 2017). Active movements documented by Lim et al. (2021) in torrential environments confirm that this threshold provides a sufficiently wide safety margin.

Comparative table of configurations

The following examples illustrate several possible intake configurations:

Configuration	Velocity at screen	Gap	Desman risk	Verdict
Fine screen, no velocity control	> 75 cm/s	15 mm	Clogging → fatal impingement of juvenile Desmanids	◍ **DANGEROUS**
Fine screen, intermediate velocity	50–75 cm/s	15 mm	Possible clogging → impingement risk	◌ **INSUFFICIENT**
Dual criterion — recommended	< 35 cm/s	≥ 20 mm	Little critical clogging. Desman moves away effortlessly.	✔ **PROTECTIVE**

4. Proposal for a proportionate dual protection criterion

4.1. Criterion 1 — Aspiration velocity ≤ 35 cm/s

Maximum aspiration velocity: 35 cm/s
At this velocity, the pressure exerted by the flow is below the Desman's swimming capacity at minimal effort. The animal spontaneously moves away from the screen and continues its natural movement.
This velocity is consistent with the operator's objectives: 25 to 50 cm/s to prevent clogging and protect the turbine.

4.2. Criterion 2 — Protective bar spacing ≥ 20 mm

Protective bar spacing: ≥ 20 mm (20–50 mm according to sediment context)
A protective bar spacing of 20 to 50 mm, adapted to the sediment context, prevents physical passage of the animal's body while maintaining sufficient filtering surface to limit critical clogging.

4.3. Method for calculating velocity at the screen surface

General formula: V (m/s) = Qmax (m^3/s) / Swetted (m^2)
Effective wetted area: Swetted = Width × Submerged length × R
Gap ratio: R = e / (e + b)
Where:

- V: aspiration velocity at the screen surface (m/s)
- Qmax: maximum captured flow (m^3/s)
- Submerged screen width (m)
- Submerged length (m)
- e: gap — free spacing between bars (m)
- b: bar width (m)

Note: Once the individual is against the screen surface, the actual velocity it must swim against to move away is the inter-bar velocity, not the average velocity before being against the screen. This justifies calculating the actual inter-bar velocity.

Case study No. 1 — Well-dimensioned plant: dual criterion satisfied ✅

- Qmax: 2,000 l/s = 2.000 m^3/s
- Screen width: 4.00 m
- Submerged length: 3.00 m
- Gap: 20 mm, bar thickness: 5 mm
- Gross wetted area: 4.00 m × 3.00 m = 12.00 m^2
- Gap ratio: 20 / (20 + 5) = 20 / 25 = 80%
- Wetted area: 12.00 × 0.80 = 9.60 m^2

V (m/s) = 2 m^3/s / 9.60 m^2 = 0.208 m/s = 20.8 cm/s
→ Velocity < 35 cm/s — The Desman passes in front of the intake, crosses the watercourse, returns to the bank and lives around this structure without any danger. ✅

Case study No. 2 — 15 mm screen: LIFE+ 2020 compliant, dangerous in operation 🔴

- Qmax: 2 m^3/s
- Screen width: 3 m
- Submerged length: 2 m
- Gap e = 15 mm | Bar b = 5 mm
- Gross area: 3 m × 2 m = 6 m^2
- Gap ratio: 15 / (15 + 5) = 15 / 20 = 75%
- Wetted area: 6.00 × 0.75 = 4.50 m^2

V = 2.000 / 4.50 = 0.44 m/s = 44 cm/s
→ Already > 35 cm/s at commissioning 🟠
With 30% clogging (common operational state):

- Remaining active area: 70%
- Clogged wetted area: 6.00 × 0.75 × 0.70 = 3.15 m²

V = 2 m³/s / 3.15 = 0.63 m/s = 63 cm/s
→ Exceeds the maximum swimming capacity of juveniles (≈ 35 cm/s). Fatal trap.

Juvenile Desmanids, whose swimming capacity is lower than adults, constitute the most vulnerable population. They are precisely those that the 15 mm gap prescription claims to protect — and whom it places in mortal danger.

4.4. Inseparability of the two criteria

- Velocity alone, without protective bar spacing, does not protect against accidental passage of the animal into the penstock.
- Gap alone, without velocity control, creates an impingement and clogging risk.

These two criteria are complementary and must be verified jointly in any authorisation file.

5. Proposal for administrative files and prescriptions

What an administration may legitimately prescribe:
- Justification of the aspiration velocity at the screen surface (V < 35 cm/s).
- A gap of between 20 mm and 30 mm, justified by the Desman's body dimensions.
- Adaptation of the screen surface if necessary to achieve a velocity below 35 cm/s.

What an administration may not prescribe without proportionate justification:
- A 15 mm gap without verification of the corresponding aspiration velocity.
- Coanda screens for intakes with a forebay operating at a velocity below 35 cm/s.
- Identical prescriptions for small plants (< 4,500 kW), if they comply with the above criteria and without proportionality analysis.

6. Conclusion

The "fall" risk described by Lim et al. (2020) is physically non-existent in the context of high-head hydroelectric plant intakes fitted with a forebay ($\Delta h \approx 0$). The actual risk for the Desman is impingement against clogged screens, whose prevention rests exclusively on controlling velocity at the screen surface.

Prescribing a gap below 15 mm, without consideration of screen velocity, produces a fatal endangerment effect — the opposite of the intended protection — by accelerating clogging and transforming the recommended fine screen into a fatal trap for juvenile Desmanids.

Note on the proposed 35 cm/s threshold value:

The 35 cm/s velocity retained as the critical threshold at the screen surface constitutes a default value, established by application of the precautionary principle (Article L.110-1 of the

Environmental Code) in the absence of published data on the swimming capacity of juvenile Pyrenean Desmanids. This value corresponds to half the documented swimming capacity of adults during hunting activity (> 70 cm/s, Biffi et al., 2017; Lim et al., 2021). The proposed threshold is open to revision as soon as direct measurements of juvenile swimming capacity become available in the scientific literature. The authors invite competent research organisations — in particular CEN Occitanie and the PNA Desman partner laboratories — to integrate this measurement into their study protocols.

Proposed dual criterion — inseparable:
1. Screen velocity < 35 cm/s (half the documented current velocity for adults at minimal swimming effort)
2. Protective bar spacing ≥ 20 mm (passive protection function, without critical clogging risk)
This dual criterion meets the objectives of the second PNA Desman 2021-2030. This note is intended to serve as an operational reference in Water Act authorisation files, and to contribute to harmonisation of administrative prescriptions in the Pyrenean zone. The 35 cm/s threshold constitutes a default value, open to revision as soon as data on juvenile Desmanid swimming capacity become available in the scientific literature.

This paper will be updated according to feedback, with a view to stabilising a falsifiable, reproducible method with homogeneous criteria for the Pyrenees.

Bibliographic references

- Biffi, M. (2017). Influence des facteurs environnementaux et des interactions biotiques sur la sélection de l'habitat et le régime alimentaire du Desman des Pyrénées, Galemys pyrenaicus. Doctoral thesis, Ecolab, Université Paul Sabatier, Toulouse.
- CNPN (2019). Opinion on the assessment of the National Action Plan for the Pyrenean Desman (Galemys pyrenaicus) 2009-2015. ECB Commission of the CNPN, 19 December 2019.
- Jacob, F. (2020). Hydroelectricity and the Pyrenean Desman. EDF. LIFE+ Desman restitution colloquium, December 2019, Toulouse.
- Lim, M., Xéridat, P., Némoz, M. et al. (2020). Booklet 4 — Technical guidance for the management of the Pyrenean Desman and its habitats. CEN Midi-Pyrénées, 86 p.
- Némoz, M. & Baran, P. (2020). Minimum biological flow for the Pyrenean Desman. CEN Midi-Pyrénées / ECOGEA. LIFE+ Desman colloquium, December 2019.
- Lim, M., Blanc, F., Michaux, J., Pigneur, L.-M., Gillet, F., Marc, D., Poncet, É. & Némoz, M. (2021). Comparative study of density and movements of Pyrenean Desmans (Galemys pyrenaicus) using a non-invasive method. Naturae 2021 (17): 233-242. https://doi.org/10.5852/naturae2021a17
- Poncet, E., Némoz, M., Blanc, F. & Lim, M. (2020). LIFE+ Desman, and then? CEN Midi-Pyrénées, May 2020.